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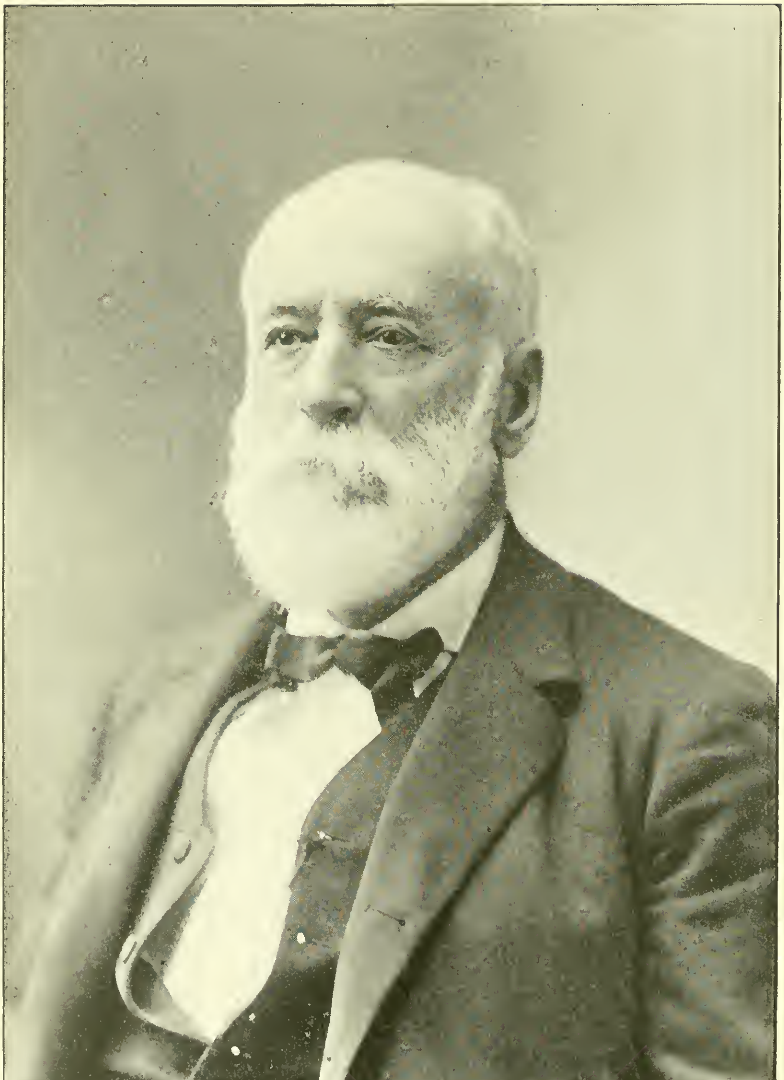

THOMAS DOANE.

President Boston Society of Civil Engineers, 1874-80 and 1880-84.

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DOCK EQUIPMENT FOR THE RAPID HANDLING OF COAL AND ORE ON THE GREAT AMERICAN LAKES.

BY ARTHUR C. JOHNSTON, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club January, 1900.*]

SIR WILLIAM H. WHITE, director of naval construction in the British navy, in a recent review before the Institution of Mechanical Engineers, says: "One of the most marked tendencies in recent construction has been the increase in size and carrying power of ships. Unless there had been a corresponding development in the means of dealing with cargo this increase in size could hardly have occurred, and the advantages resulting from that increase would not have been realized." And further he says: "It is well recognized that unless there is 'quick dispatch' in loading and unloading cargoes very serious diminutions of earnings must result from the longer detention in port. Hence it follows that for the complete commercial success of the larger classes of cargo carriers lifting appliances of the most efficient character and of ample capacity are of the greatest importance." If this is true of ocean-going vessels, where voyages are, on the average, comparatively long and extended, to a much greater extent is it true of vessels carrying cargo on the Great Lakes, where, even with rapid loading and discharging of cargoes, the ratio of time spent in port to that spent in transit is very great, amounting to one-sixth under the most favorable circumstances. The object of this paper is to deal with the special types of machinery built for the purpose of insuring "quick dispatch" in loading and unloading the enormous tonnage of ore and coal that is shipped annually on the Great Lakes, the founda-

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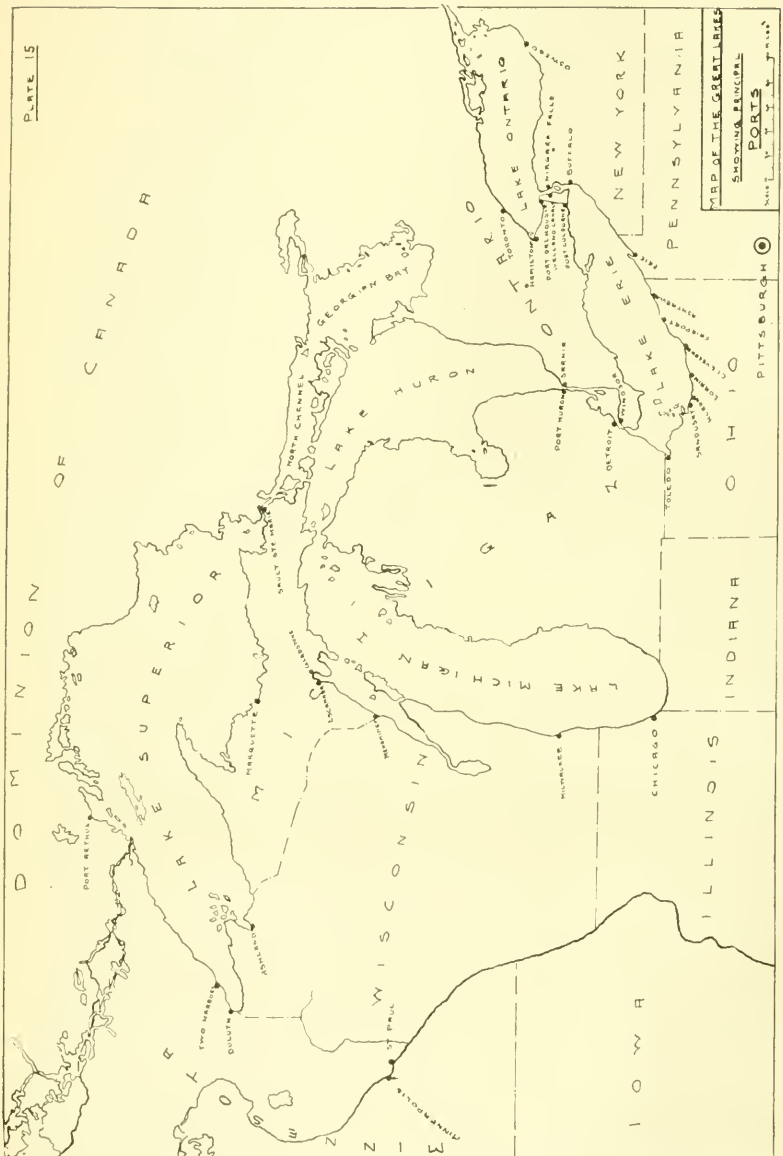


PLATE 15
MAP OF THE GREAT LAKES
SHOWING PRINCIPAL
PORTS
DOMINION OF CANADA
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
NORTH CHANNEL
LAKE ONTARIO
LAKE ERIE
NEW YORK
PENNSYLVANIA
OHIO
INDIANA
ILLINOIS
IOWA
WISCONSIN
MICHIGAN
MINNESOTA
PORT ARTHUR
DULUTH
TWO HARBORS
ASHLAND
MARQUETTE
SAULT STE MARIE
ESCANABA
MENOMINEE
MILWAUKEE
CHICAGO
ST PAUL
MINNEAPOLIS
PORT HURON
SARNIA
DETROIT
WINDSOR
TOLEDO
SANDUSKY
TORONTO
HAMILTON
PORT DALHOUSIE
WELLAND CANAL
PORT COLBORNE
NIAGARA FALLS
BUFFALO
OSWEGO
ERIE
PITTSBURGH

FIG. 1.

tion of the gigantic steel industry that has made the United States a competitor in the markets of the world.

The shipments of ore from Lake Superior iron ranges represent roughly one-third of the entire freight traffic on the lakes, and for this reason a large fleet of modern cargo vessels has been built specially for this trade, represented as a type by the tow barge shown in Fig. 2, the steam barges being of the same general type. The largest of these are 500 feet long and 50-foot beam, the distinctive feature of these boats being the large size and number of hatches—30 to 34 feet long by 8 feet wide, spaced 24 feet center to center along the entire available deck length. This greatly facilitates loading and unloading operations, at the expense, however, of the strength of the deck plating, since the ship is almost cut in two crosswise of her deck.

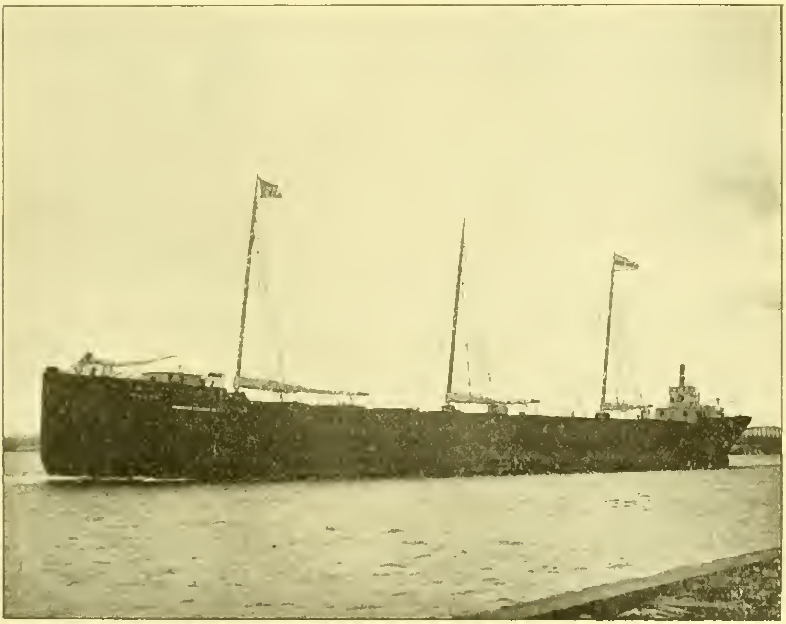


FIG. 2. TOW BARGE "MAGNA." GROSS TONNAGE 3259. NET TONNAGE 3124. KEEL 352 FEET. BEAM 44 FEET.

In Fig. 3 is shown the cross-section of a typical ore-loading dock and the method of loading vessels. The ore is dropped into the pockets from drop-bottom "Jumbo" cars running on the tracks above, and from the pockets the chutes discharge the ore into the vessels lying alongside the dock. At the end of the season of 1898 there was, at the different points, a total of 4354 pockets, having a

total storage capacity of 623,612 gross tons of ore, constructed at a cost of about $7,000,000. The following table gives a list of docks, with principal dimensions and location, and the names of the railway companies owning them:

Railway.	Location.	Dock No.	Length of Dock in Feet.	Width of Dock in Feet.	Height of Dock Water to Deck.	No. of Pockets.	Storage Capacity. Gross Tons.
Duluth and Iron Range R. R. Co.	Two Harbors, Minn.	1	1,056	41′0″	45′6″	141	18,000
		2	1,248	......	57′0″	208	41,600
		3	540	49′0″	51′6″	90	16.000
		4	1,008	49′0″	51′6″	168	30,000
		5	1,008	49′0″	54′0″	168	33,000
Duluth, Masaba and Northern.	Duluth, Minn.	1	2,340	52′0″	53′6″	384	57,600
		2	1,738	52′0″	57′4″	288	42,400
Duluth, Superior and Western Ry.	Allouez Bay Superior, Minn.	1	a- 300	49′8″	52′0″	40	12,000
			b-1,200	49′8″	57′0″	190	25,500
Chicago and Northwestern R. R.	Ashland, Wis.	1	1,404	46′8″	54′0″	234	36,036
		2	1,404	46′0″	58′8″	234	24,156
	Escabana, Mich.	1	1,404	37′0″	46′0″	184	24,104
		3	1,356	37′0″	39′0″	226	30,284
		4	1,500	37′0″	59′2″	250	37,500
		5	1,392	37′0″	51′10″	232	43,152
Duluth, South Shore and Atlantic R. R.	Marquette, Mich.	1	1,700	40′0″	45′0″	270	27,000
		3	1,200	53′6″	37′0″	213	12,780
		4	1,200	36′8″	47′3″	200	28,000
Lake Superior and Ishpeming.	Marquette, Mich.	1	1,200	52′0″	54′0″	200	36,000
Minneapolis, St. Paul and Sault Ste. Marie R. R.	Gladstone, Mich.	1	768	37′0″	47′0″	120	15,000
Wisconsin Central Lines.	Ashland, Wis.	1	1,908	36′0″	54′6″	314	33.500

The Duluth, Masaba and Northern Railway has now under construction a new dock which is 66 feet 6 inches in height, 62 feet in width, the heel of the spout being 40 feet above the water line. There will be 192 pockets, with a capacity of 210 tons each. The additional width permits the placing of a track along the center of the dock for storing empty cars and minimizing the work of the switching engines. The dock proper will require 6,500,000 feet of sawed timber and 4780 pieces of piling.

The pockets of these docks can be filled with the different grades of ore ready to be discharged into the vessels as they arrive, and it is not an uncommon thing for a vessel to come alongside of one of these docks, take on a cargo of 5000 tons of ore and depart within two or three hours from the time it reached port. In the busy seasons, however, the vessels are loaded directly from the cars by dropping the ore through the pockets. Timbers are placed across the lower hatch to break the fall of the ore, and, with proper manipulation of the chutes, an entire cargo can be loaded with little or no trimming.

The following table gives the output of the Lake Superior ranges from 1896 to 1899, inclusive:

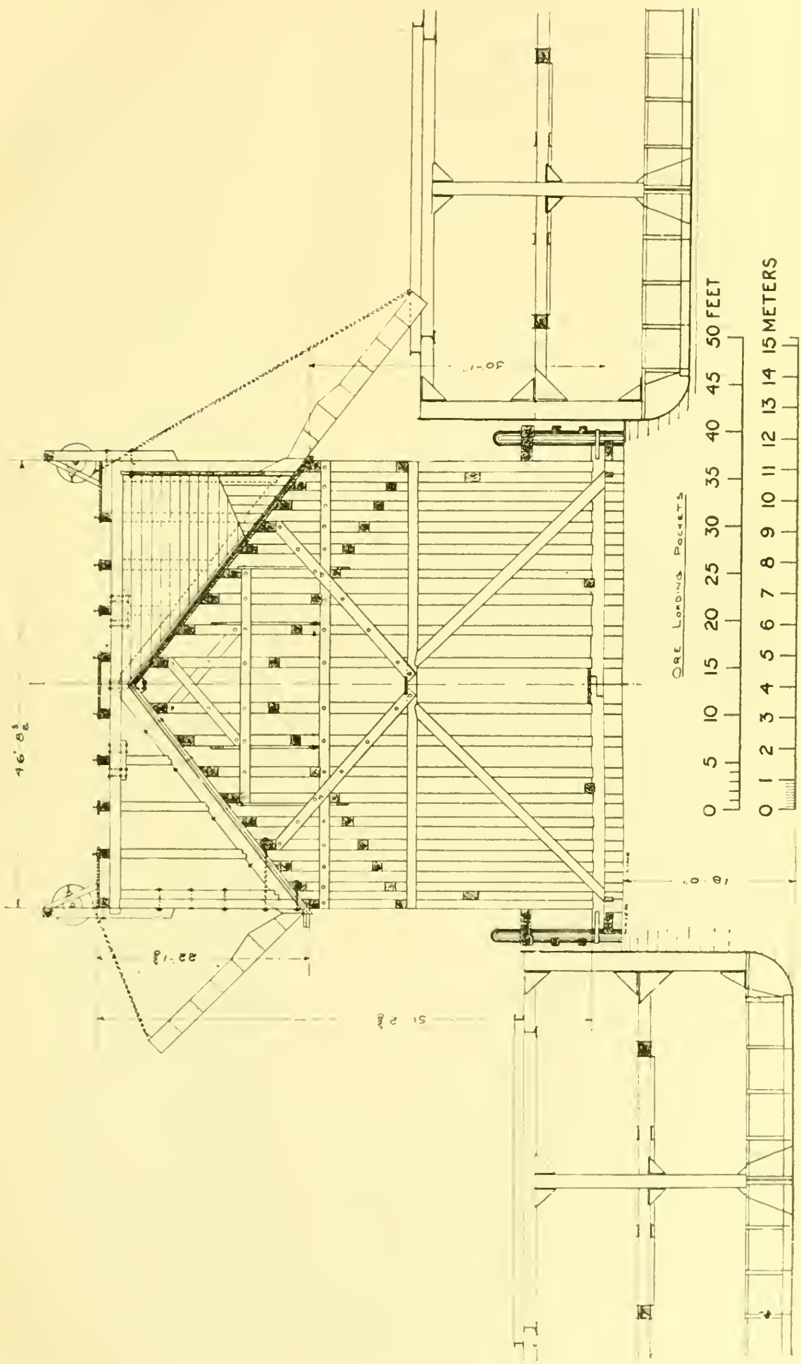

Ore Loading Pockets
0 5 10 15 20 25 30 35 40 45 50 FEET
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 METERS

Fig. 3.

OUTPUT OF IRON ORE FROM ALL MINES OF THE LAKE SUPERIOR ORE REGION, 1895 TO 1899, INCLUSIVE.

Ports.	1899.	1898.	1897.	1896.	1895.
Escanaba	3,720,218	2,803,513	2,302,121	2,321,931	2,860,172
Marquette	2,733,596	2,245,965	1,945,519	1,564,813	1,079,485
Ashland	2,703,417	2,391,088	2,067,637	1,566,236	2,350,219
Two Harbors	3,973,733	2,693,246	2,651,465	1,813,992	2,118,156
Gladstone	381,457	335,955	341,014	220.887	109,211
Superior	878,942	550,403	531,825	167,245	117,884
Duluth	3,509,965	2,635.262	2,376,064	1,988.932	1,598,783
Total by lake	17,901,358	13,655,432	12,215,645	9,644,036	10,233,910
Total by rail		369,241	253,993	290,792	195,127
Total shipments	17,901,358	14,024,673	12,469,638	9,934,828	10.429,037

Practically all this ore is unloaded at South Chicago for consumption there, or at some of the Lake Erie ports for consumption in the Pittsburg district. The relative locations of these places will be seen on the map in Fig. 1. One of the most recent and largest installations of ore-unloading equipments is the plant on the docks of the Lorain Steel Company, built by the McMyler Manufacturing Company, and shown in Fig. 4. The plant consists of four machines of three bridges each, the distinctive feature being the long cantilever of 127 feet overhanging the boat and the great length of bridge. On a return trip from the bottom of the boat to the extreme end of the rear cantilever the bucket travels 940 feet. As will be seen, the ore can be dumped on the stock piles, or through the suspended hoppers into cars, which carry it to the furnaces situated directly behind the hoists. In Fig. 5 is shown the wagon and front stop used on these machines, and Fig. 6 is a detail of the 20-cubic-foot bucket used. The most economical size of bucket for use in connection with ore hoists has been found to be from 17 to 20 cubic feet capacity, as a larger bucket is so heavy for the shovelmen to handle that much time is lost. Seventeen cubic feet contain one gross ton of light soft ore or 2500 pounds of hard ore. Each bridge of the conveyors shown in Fig. 4 is equipped with a pair of 12 x 12-inch non-reversing engines carrying a 40-inch drum directly on the crank-shaft for the main hoisting rope. As will be seen from Fig. 5, the wagon is arranged with a "three-part" hoist, but in traveling along the bridge the full circumferential speed of the drum is effective on the wagon; so that a single revolution of the engine carries the wagon 10 feet 5 inches along the bridge in trolleying, or lifts the bucket 3 feet $5\frac{5}{8}$ inches in hoisting, thus making the machines very quick in action. In returning the wagon, the incline of the bridge is aided by a counterweight in the rear tower. The main hoisting ropes are $\frac{5}{8}$ inch in diameter ($\frac{1}{2}$-inch ropes having been found too light for the severe service), running on 24-inch sheaves, except in the wagon, where

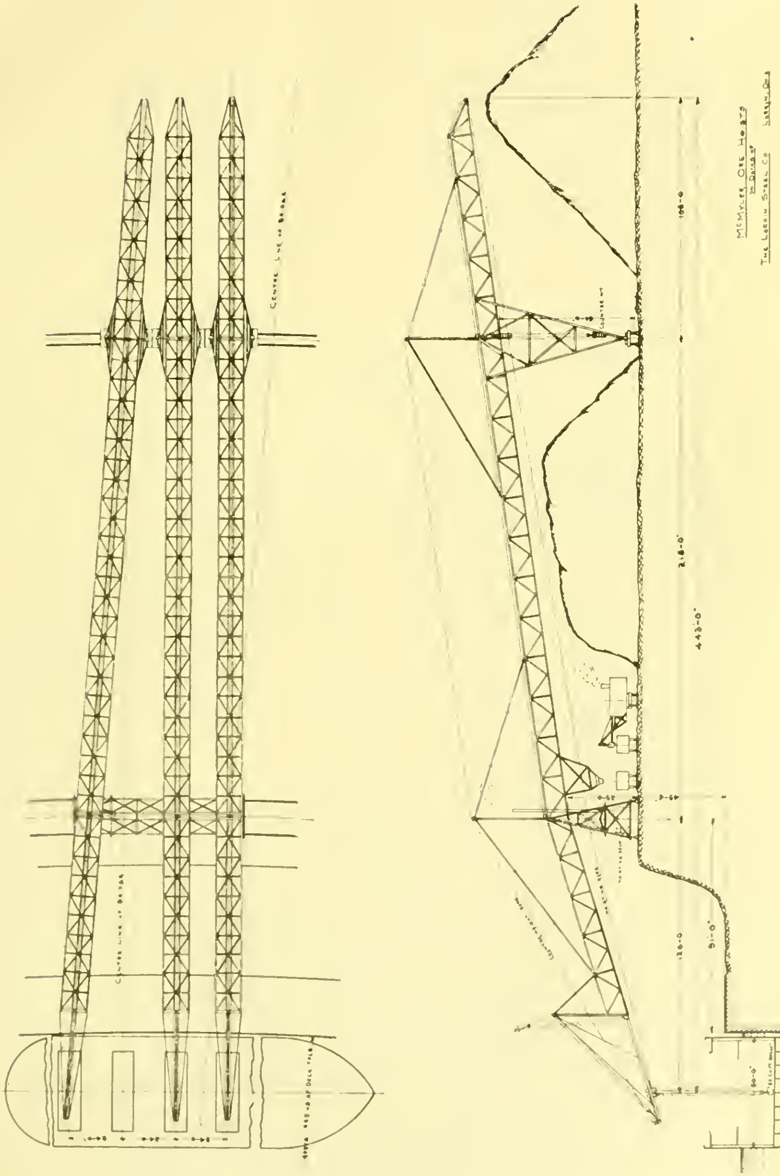


FIG. 4.

they are 17 inches, and in the hanging block, where they are $14\frac{1}{2}$ inches in diameter. The engines have auxiliary drums for hoisting the boom or apron that overhangs the boat, and they are also arranged to move the front end of the bridges in or out from the center bridge in order to accommodate any spacing of hatches and to propel the front tower along the track parallel to the dock face. The rear towers are moved by a locomotive on a parallel track. The returning wagon is controlled by a band brake on the drum, worked by the foot of the operator. These machines have made some remarkable records in point of speed, as an individual wagon has made fifty return trips per hour, carrying the bucket from the

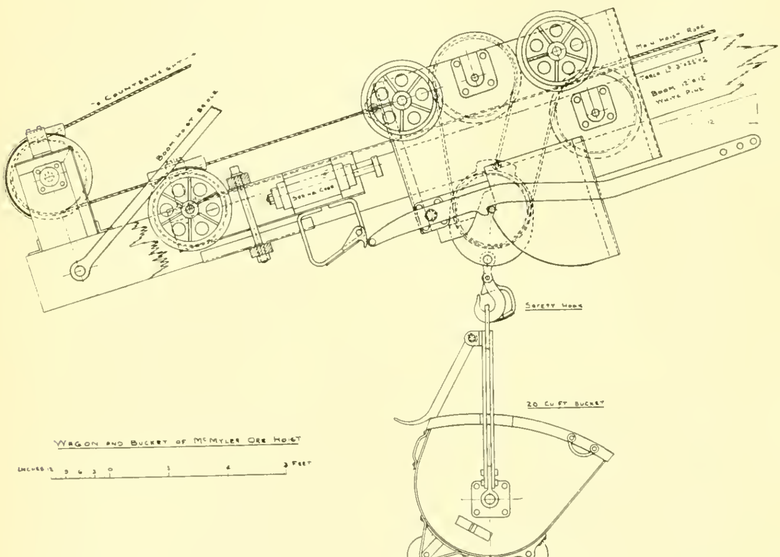


Fig. 5.

bottom of the boat to a point halfway between the towers. The best cargo record was 3241 gross tons taken out in twelve and one-half hours by six bridges. The operator is located in the front tower in these machines, in full view of the hatch, which makes the matter of getting the bucket up and down through the hatch much easier and quicker than when he is further removed from the boat.

In Fig. 7 is shown the type of unloader built by the Brown Hoisting and Conveying Machine Company, the pioneers in the building of dock machinery on the lakes. It differs from the McMyler hoists, already described, in the type of towers employed and in the arrangement of the towers. The engines also have a single reduction gearing between the crank-shaft and drum, thus

using a smaller engine with higher piston speed. The machines are generally arranged in groups of two, with the engines and boilers and operators in the rear tower. Both towers are generally moved along the dock by hand. There are over 175 bridges of the Brown type of conveyor at the different Lake Erie ports.

In Fig. 8 is shown yet another type of ore unloader, built by the King Bridge Company. Its distinctive feature is the great freedom of motion of the bucket. In both the Brown and the McMyler type the hanging block is locked in the wagon, and cannot be released without striking a stop which is bolted between the tracks. Thus, when unloading very narrow boats, the front stop on the apron must be moved in till it is vertically over the center of the

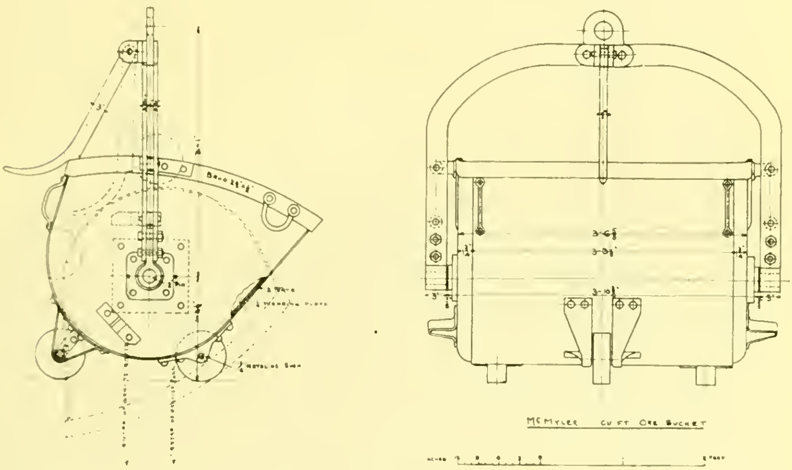


Fig. 6.

hatch, and, similarly, for loading into a car on a track under the rear cantilever a stop must be placed over the center of the track to allow the bucket to be lowered in order to reduce the drop of the ore. In the King machines, however, the bucket can be raised or lowered to any desired height simultaneously with its travel along the bridge. The dock records of Conneaut Harbor show that nothing is lost in point of speed of operation, and, considering its advantages, it is surprising that the system has not been used to a much greater extent; its only disadvantage being that three drums and reversing engines are required for its operation.

When railway cars are always available "direct unloaders" are used to transfer the ore directly to cars. The latest plant of this kind is that shown in Figs. 9 and 10, built by the McMyler Manufacturing Company for the Pittsburg and Conneaut Dock Company,

at Conneaut, Ohio. These machines have attracted a great deal of attention, and a description of their equipment will be of interest. Each machine, complete in itself, carries three bridges, which can be racked in and out to suit any spacing of hatches from 21 to 36 feet centers. The bridges cover five loading tracks, and are high enough to acommodate the largest lake vessels. An 80 H. P. locomotive-type boiler supplies steam to three pairs of $10\frac{1}{2}$ x 14-inch reversing engines. Each pair of engines has 40-inch drums for both hoisting and trolleying, mounted on the crank-shaft, the

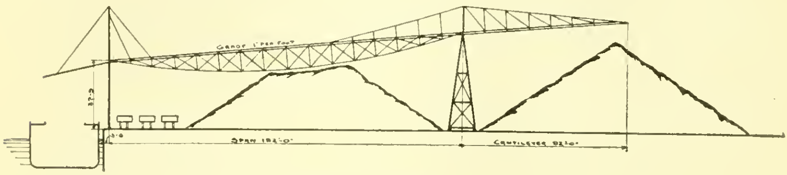


Fig. 7. Brown Type Ore Hoist.

wagon having a three-part hoist. A feature of the arrangement of the engine is the method of controlling the clutch and brake for the trolleying drum, by using a steam cylinder, which, when it sets the brake, at the same time releases the clutch, and *vice versa*. Nine-sixteenths-inch cables are used for hoisting, running on 24-inch sheaves, except in the wagon, where they are 17-inch, and in the hanging block 15 inches in diameter. . It is made impossible for a rope to leave the sheave by the use of the very simple guard shown in Fig. 11. The machines can travel along the dock by steam, and

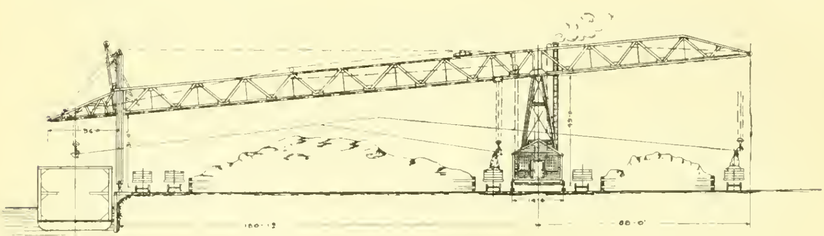


Fig. 8.

the racking of bridges is also effected by the engines. All movements other than hoisting and trolleying of the bucket are accomplished by means of a jack-shaft driven by a pinion on the crank-shaft of the main engines. Under actual working conditions the capacity of the plant of twelve bridges at Conneaut is 6000 gross tons per day.

In a similar direct unloading plant built by the Brown Hoisting and Conveying Machine Company on the C. and P. docks at Cleve-

land the drum is geared to the crank-shaft, and the "suspended hook" is used. In neither the Brown nor the McMyler direct unloaders is the hanging block locked in the wagon, except to obtain the maximum clearance under the bucket. The lock on the wagon is very handy, however, to hang empty buckets from when the machine is idle.

With all these machines, in which the buckets are filled by hand, the actual cost of handling the buckets is very small, varying according to how nearly up to its full capacity a machine is worked; but under actual working conditions, from figures prepared by Mr.

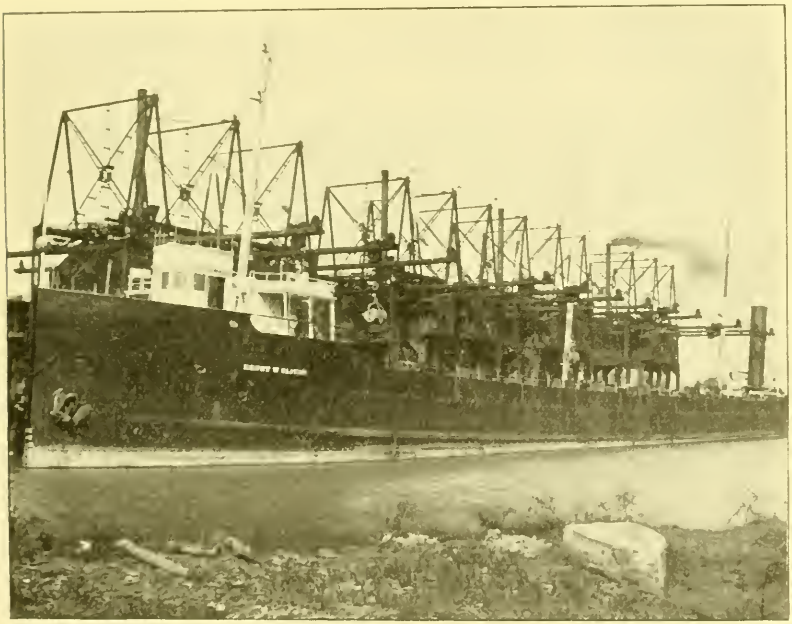


FIG. 9. McMYLER DIRECT ORE UNLOADERS. PITTSBURG AND CONNEAUT DOCK CO., CONNEAUT, OHIO.

A. E. Brown, the cost per gross ton of ore handled by his machines varies from 0.7 cent to 1.37 cents. But the greatest expense is incurred in filling the buckets. The shovelmen are paid from 10½ cents to 13 cents per gross ton, so that, at an average rate of 11 cents per ton, it cost $1,980,000 for shoveling to unload the 18,000,000 tons of ore shipped this year. It was to reduce this cost that the Hulett ore unloader, shown in Figs. 12, 13 and 14, was designed and built by the Webster, Camp & Lane Machine Company for the Pittsburg and Conneaut Dock Company at Conneaut. Up to the present not enough has been done with this machine to obtain any

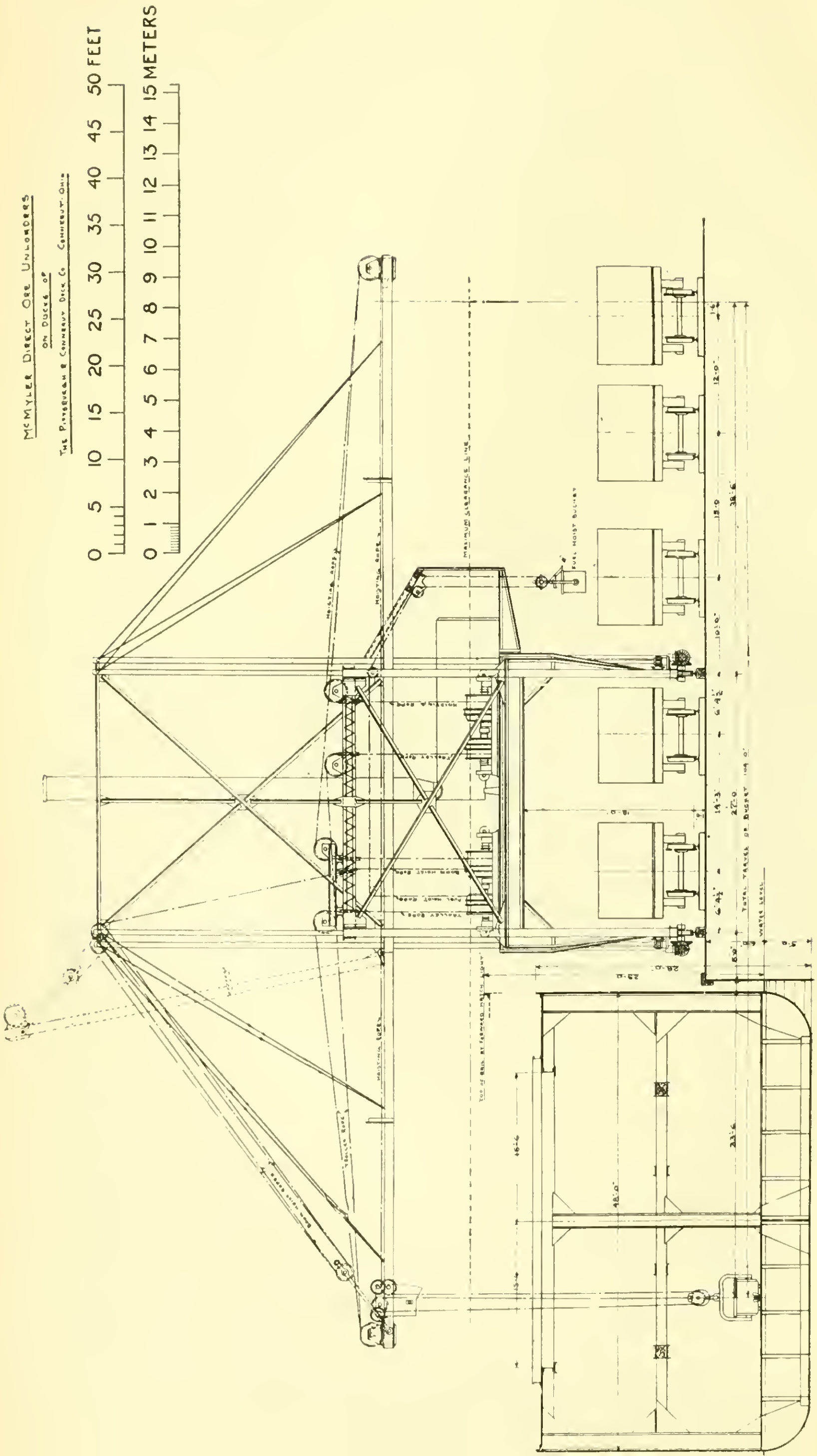

McMyler Direct Ore Unloaders
on Docks of
The Pittsburgh & Conneaut Dock Co. Conneaut, Ohio
0 5 10 15 20 25 30 35 40 45 50 FEET
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 METERS
Maximum Clearance Line
Fuel Hoist Bucket
Water Level

FIG. 10.

data in regard to its performance. Its method of operation will be evident, however. The bucket is designed to lift 10 tons of ore at one scoop and dump it into the railway cars, or into a skip which can deliver it to the stock piles. All the motions on the trolley carrying the tilting girder are effected by hydraulic power, the pumps and tank being carried on the trolley itself, and the steam-loaded accumulator is used to partly balance the weight of the bucket. The operator is located just above the bucket, and descends into the hatch with it. The bucket can rotate in either direction about the axis of the vertical ram, thus enabling the ore lying in between hatches to be reached. It is expected that very little of the ore will have to be shoveled by hand with this machine.

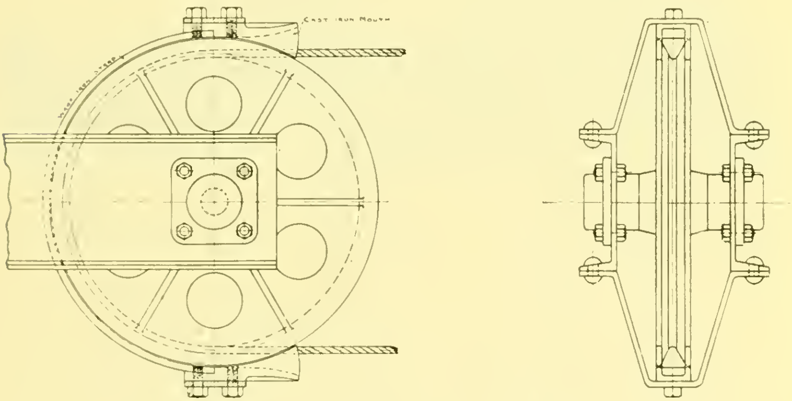


FIG. 11. ROPE GUARD FOR SHEAVES.

The large vessels returning from the lower lake ports go up in water ballast or take a return cargo of coal; and to facilitate the loading of the enormous tonnage that is carried to the upper lake ports each year the car dumper has been developed,—a machine which picks up bodily a car weighing 17½ tons and carrying 40 tons of coal and empties the contents into the hold of a vessel at the rate of as high as thirty cars per hour. Fig. 15 shows the first type of McMyler "side dump" machine built on the lakes. The first successful machines were of the "end dump" type, but they require special cars. They are still in operation, one at Ashtabula and one at Fairport. The machine shown in Fig. 15 is very flexible in operation, as the hinge of the aprons may be raised or lowered vertically to suit any class of vessel, and the car and cradle in ascending begin to turn over on striking the hinge point of the apron. This machine has been built with several types of chutes, but perhaps the most successful is the telescopic chute shown, as by

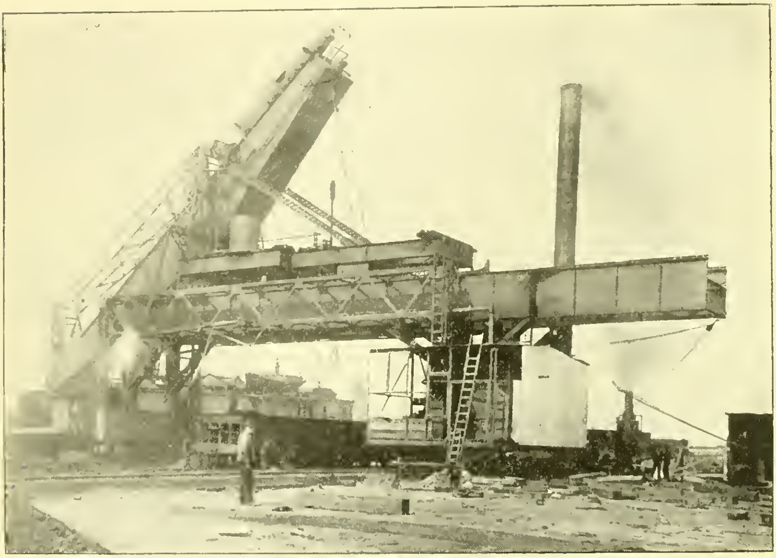


FIG. 12. HULETT ORE UNLOADER BUILT BY THE WEBSTER, CAMP & LANE MACHINE CO. FOR THE PITTSBURG AND CONNEAUT DOCK CO.

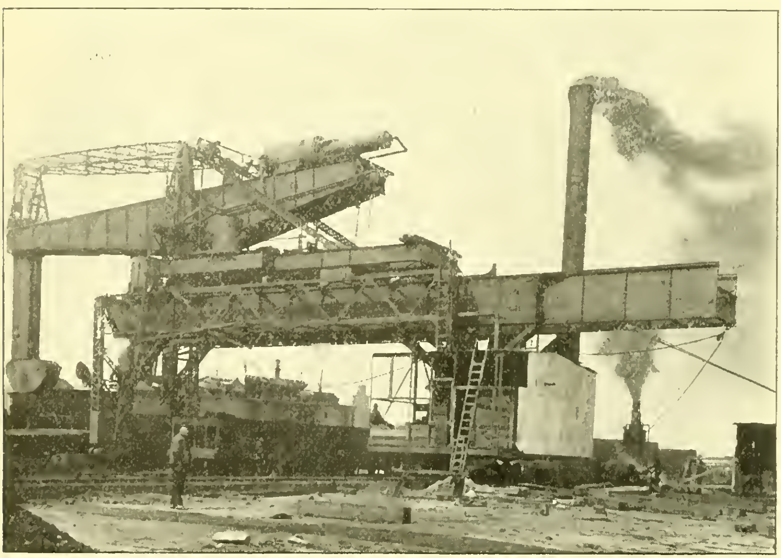


FIG. 13. HULETT ORE UNLOADER.

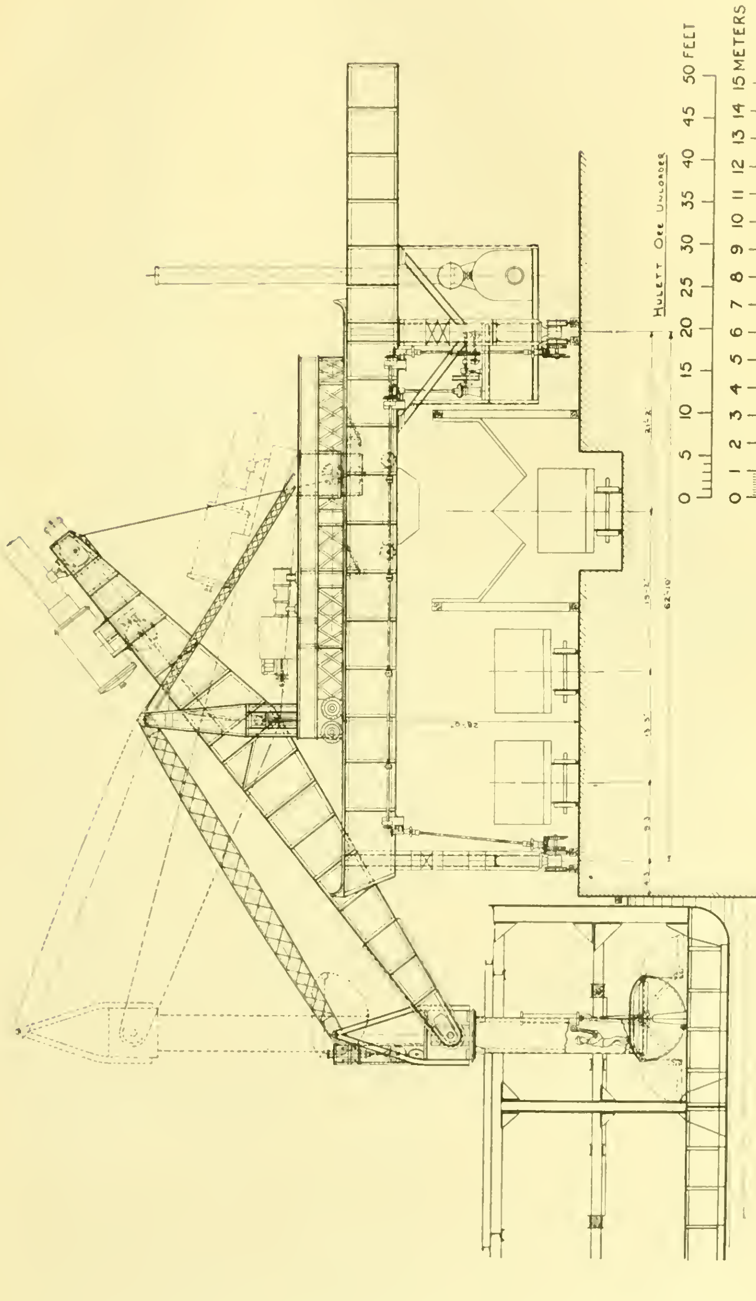

HULETT ORE UNLOADER
0 5 10 15 20 25 30 35 40 45 50 FEET
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 METERS
62'-10"

FIG. 14.

its use much trimming of cargo is avoided. The car-clamping mechanism is beautifully simple, being merely four chains with counterweights suspended, the chains wrapping round the car as it is overturned. The cable is hoisted by four 1¼-inch cables arranged

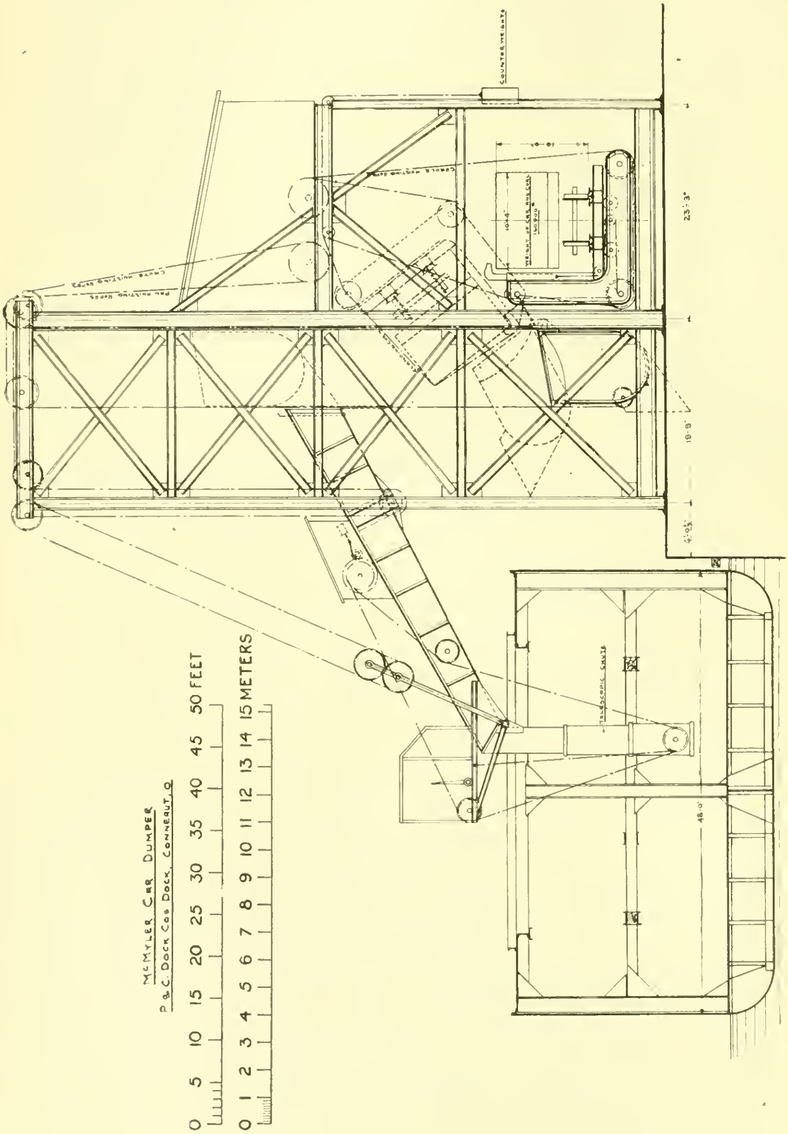


Fig. 15.

as a "two-part" hoist on 45-inch drums, driven through double reduction gearing by a pair of 14 x 18-inch engines. The load is lowered by using the engines as air pumps and throttling the exhaust, or with a foot brake, as desired. In operation the machine,

though so powerful, is extremely simple, considering the work it accomplishes, and has a record of thirty-two cars an hour; but of course this speed cannot be maintained, on account of delays in switching cars and shifting the boat to reach different hatches. There are three machines of this type in operation: one on the docks of the Cuddy-Mullen Coal Company at Cleveland, one on the docks of the Cleveland Terminal and Valley Railway at Cleveland and one at Erie, Pa., on the docks of the Erie and Pittsburg Railway.

Fig. 16 shows the latest type of McMyler car dumper; designed to handle the coal more gently, in order to reduce the breakage to as small a percentage as possible. There are also three of these

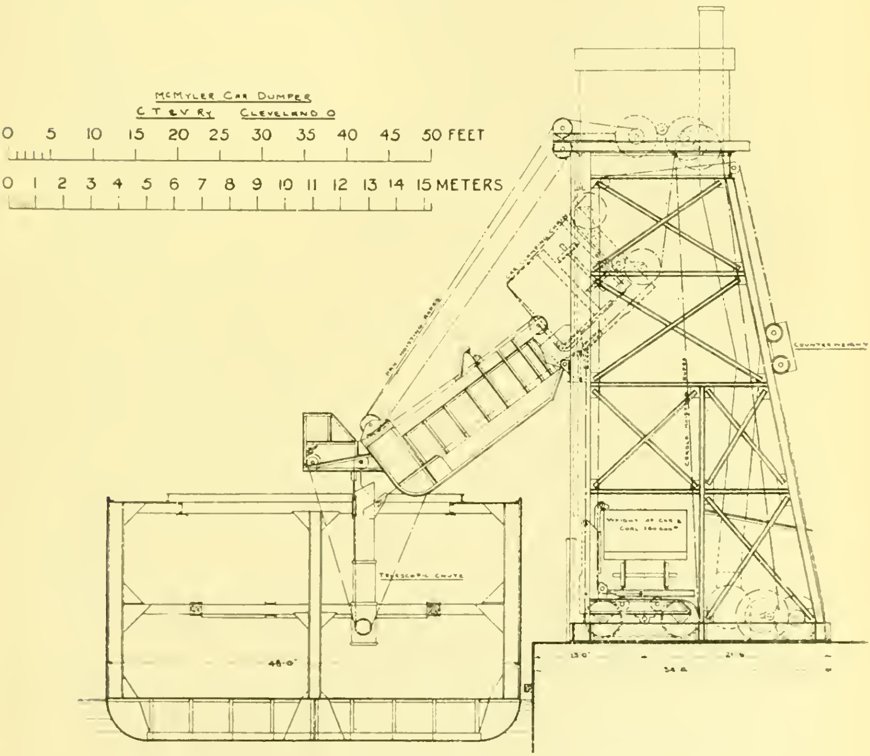


FIG. 16.

machines in operation; one operated by the Pittsburg and Conneaut Dock Company at Conneaut, Ohio, another by the Cleveland, Lorain and Wheeling Railway at Lorain and a third at Ashtabula. As will be seen, the coal is first dumped into a pan, which is partly overturned to receive the coal as it rolls out of the car. The pan is then hoisted—the car being lowered meanwhile—until the chute

is reached, when a door in the pan opens automatically and discharges the coal into the chute. This machine is also very fast, and handles regularly, under working conditions, 1000 tons of coal per hour. All the motions, with the exception of hauling the cars onto the cradle, are performed by a single pair of 16 x 18-inch engines. The car and cradle are hoisted by eight $1\frac{1}{8}$-inch cables on 60-inch drums, geared to the crank-shaft by single reduction gearing. The operations of hoisting and tipping the pan are accomplished with sixteen 1-inch ropes on four drums 40 inches in diameter. The unit stresses specified by the P. and C. Dock Company's specifications covering this machine were as follows:

UNIT STRESSES.

Direct tension machinery steel in structural work, $10{,}000\left(1+\frac{\text{min}}{2\,\text{max.}}\right)$

Tension flanges of built girders, $8{,}000\left(1+\frac{\text{min.}}{2\,\text{max.}}\right)$

Tension flanges of symmetrical rolled sections, $10{,}000\left(1+\frac{\text{min.}}{2\,\text{max.}}\right)$

Direct compression, $\left(10{,}000-30\frac{l}{r}\right)\left(1+\frac{\text{min.}}{2\,\text{max.}}\right)$

Maximum limiting value for direct compression, $\frac{l}{r}=120.$

l = length of member in inches.
r = least radius of gyration in inches.

Unstayed length of flanges for built beams, $\frac{l}{w}=16.$

Unstayed length of flanges for rolled beams, $\frac{l}{w}=20.$

l = length of unstayed flange in inches.
w = width of flange in inches.
Allowance for impact of moving loads, 50 to 100 per cent.

MACHINERY SPECIFICATIONS.

Babbitted bearing pressures.

For steady pressures—pressure per square inch × velocity of journal in feet per minute must not exceed 60,000.

For intermittent pressures, use 120,000.

For slow moving bearings (not over 100 feet per minute), use 600 pounds per square inch.

Chain and rope sheaves and drums.

For link chains, $\frac{\text{diam. of sheave}}{\text{diam. of chain}}$ not less than 18.

$\frac{\text{diam. of drum}}{\text{diam. of chain}}$ not less than 24.

Ropes, $\frac{\text{diam. of rope}}{\text{diam. of sheave}}$ not greater than $\frac{1}{30}$.

$\frac{\text{diam. of rope}}{\text{diam. of drum}}$ not greater than $\frac{1}{15}$.

For all sheaves, $\frac{\text{diam. of pin}}{\text{diam. of sheave}}$ not greater than $\frac{1}{7}$.

The Brown Hoisting and Conveying Machine Company has built five car dumpers that handle the coal still more gently, but on that account they are necessarily slower in operation. With these machines the coal is dumped from the cars into six buckets carried on a transfer car. Each of these buckets is then lifted by either of two traveling cranes, which carries it out over the boat and lowers it into the hatch, when the bottom is opened and the bucket drawn away, thus placing the coal very gently and just where wanted. The mechanical arrangements are very ingenious and well executed in securing the complicated motions necessary.

The Hulett car dumper, built by the Webster, Camp & Lane Machine Company for the Rochester and Pittsburg Coal and Iron Company at Buffalo, works somewhat on the principle of the Brown car dumper, but it is much simplified by using only two buckets; in fact, the whole machine is comparatively simple. The clamping mechanism is of the same type as that of the McMyler machine. The engines for tipping the cradle are located underneath same, while those for controlling the buckets are located on the platform on top of the machine. The tracks on which the trolleys carrying the buckets run can both be swiveled about a pivotal point by hand to suit any spacing of hatches. The machine can handle regularly twenty cars an hour, but the switching room at Buffalo is so limited that a sufficient supply of cars cannot readily be made accessible to the machine.

A novel design of car dumper is shown in Figs. 17 and 18, built by the Excelsior Iron Works Company for the Erie Coal Transfer Company at Cleveland. This is an exceedingly fast machine, and its operation is very simple. The loaded car is pushed into the cylinder by a locomotive, and the cylinder and car are turned over by a steam cylinder of long stroke operating through a "two-part" rope. In turning over the car is supported on its side by a hydraulic cylinder and clamped on top by a simple device. The machine is well adapted to its peculiar location, where the bank of the river is very high, but the fall of the coal is considerable.

In all the car dumpers the speed depends largely on the switching arrangements and on the storage capacity for loaded and empty cars. The three methods in use for bringing the loaded cars into the machine are:

First. By means of a locomotive.

Second. By storing the loaded cars on tracks having a down grade into the machine.

Third. By the use of a haulage mule similar to that shown on Fig. 19.

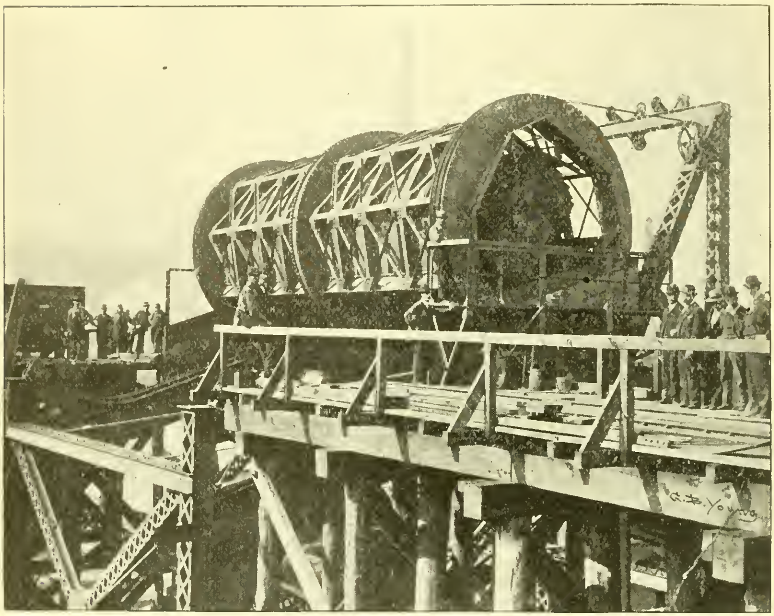


Fig. 17. Car Dumper built by the Excelsior Iron Works Co. Erie Coal Transfer Co., Cleveland, Ohio.

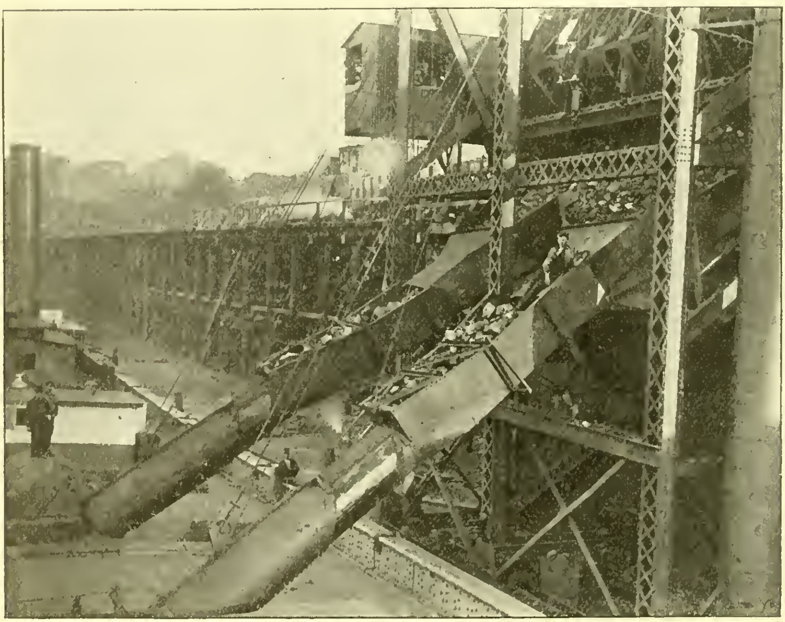


Fig. 18. Car Dumper built by the Excelsior Iron Works Co.

In the last case there is a grade up into the machine. The loaded car pushes the empty car out in all cases.

Car dumpers are also used for fueling vessels, although some of the fuel hatches cannot be reached by the chutes; but most docks handling fuel alone are equipped with coal pockets at a sufficient elevation to discharge the coal through chutes into the coal bunkers, the pockets themselves being filled by drop-bottom cars from a track carried on top. Fig. 19 shows the equipment of a large fueling block operated by the Cuddy-Mullen Coal Company at Cleveland, built specially for fueling the passenger steamers "Northwest" and "Northland." The chutes in this case are round, in order to inclose the dust. The method of hauling the coal cars up the steep grade is shown; also the ingenious method of holding the mule down to its track, thus preventing it from climbing, due to the friction between the coupler and the front of the mule.

For unloading coal at the Northern ports there are many special machines of the Brown type and others adapted to the special conditions, such as storage for railroad reshipment and wagon delivery in large cities. Many of the large mining companies also have extensive coal storage docks to tide them over the four months of closed navigation. A notable storage plant is that of the Lehigh Valley Coal Company at West Superior, Wis., in which there is storage capacity for 100,000 tons of anthracite coal under cover by the Dodge system, and for 90,000 tons of bituminous coal exposed, in piles not over thirty feet high as a precaution against spontaneous combustion. At this plant all the operations of unloading from the boats, storing and reloading into the cars are performed by machinery.

The most surprising feature in connection with the equipment of docks generally on the lakes—using the word dock in the American sense of pier or landing to which a boat ties —is that such highly improved and expensive machinery should be placed on such poor and entirely inadequate foundations; often merely a few piles driven in soft mud many feet below the water line, with little or no cross-bracing to give them some rigidity. This is probably due to the nervous speed with which a great many dock improvements and extensions have been made.

There is a growing feeling, however, in favor of great improvements in this direction, and as examples of recent construction Figs. 20 and 21 are introduced. Fig. 20 is the cross-section of a dock built by the Illinois Steel Company at their South Chicago works which has attracted a great deal of attention from engineers in this country. This dock, which is 1608 feet long, was built at the rate of about 15 feet per day. Fig. 21 is a cross-section through

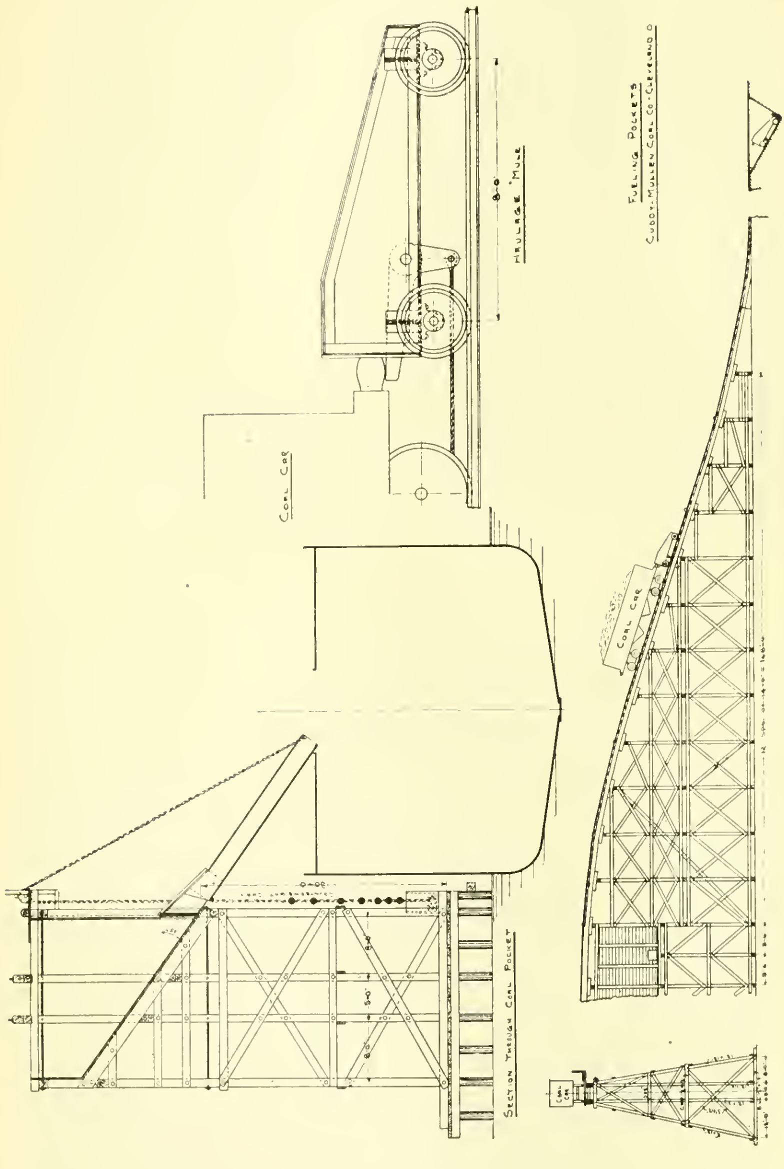

Fueling Pockets
Cuddy-Mullen Coal Co. Cleveland O
Haulage 'Mule'
Coal Car
Coal Car
Section through Coal Pocket

FIG. 19.

the foundation for the McMyler car dumper on the dock of the Pittsburg and Conneaut Dock Company at Conneaut, Ohio. This foundation has proved itself to be immovable.

It will be of interest here to quote from the "Blue Book of

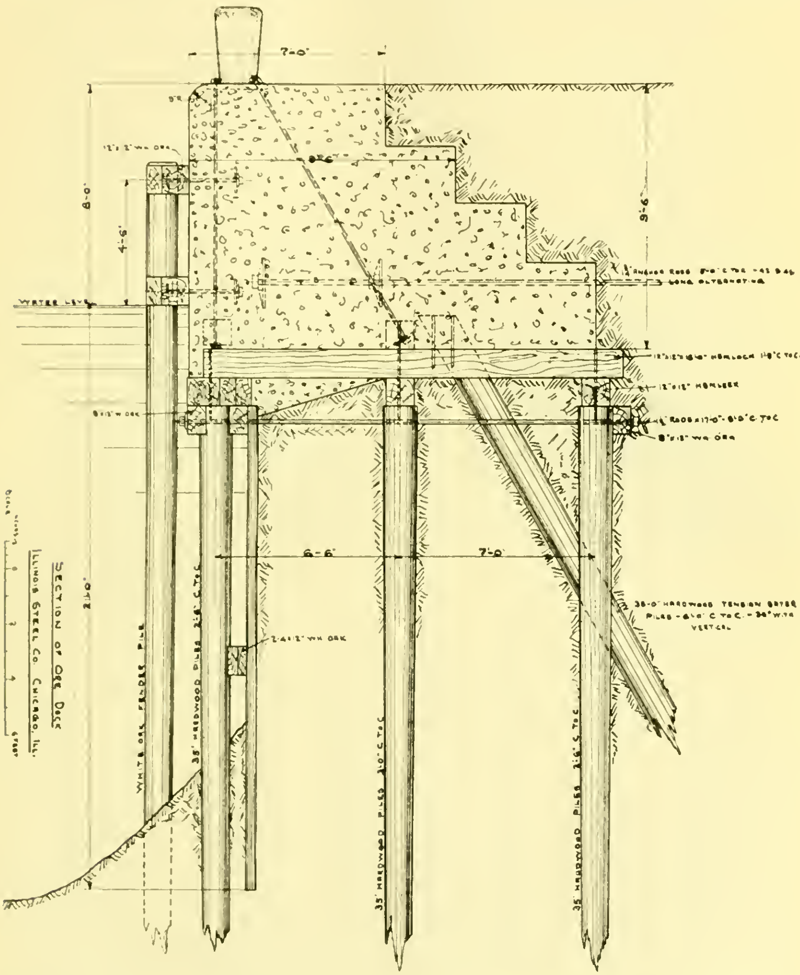
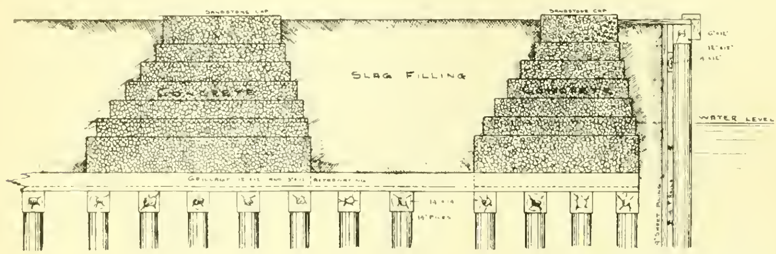


Fig. 20.

American Shipping," issued by the *Marine Review,* that on the Great Lakes there are "the greatest iron mining resources, most rapid cargo-handling facilities and the most efficient iron-producing plants in the world," together with the statement that "it is possible to take ore from the mountain iron mine and convert it into steel ship plate within ten days." While not becoming responsible for the accuracy of the last statement, quoting from the same source, the explanation is as follows:

"Suppose that on the first day and night of a month 9000 tons

were mined and loaded. The second day at noon this ore could be run onto the Duluth, Mesaba and Northern Railway docks at Duluth, 80 miles from the mine, and dumped into pockets. Each of the two docks lacks 600 feet of being one-half mile long, and both have capacity for 100,000 tons of ore. In one hour the 9000 tons could be loaded into a Bessemer steamer and barge, 424 and 366 feet long respectively. The Bessemer fleet consists of ten steamers and eleven barges, and the carrying capacity of the fleet for one season, between eight and nine months, is over 1,500,000 tons. At one o'clock on the second day the steamer and consort would start on their 890-mile trip. On the sixth day at one o'clock they would arrive at Conneaut, Ohio, the steamer, we will say, going to the McMyler rapid direct-unloading plant and the consort to the Brown



Foundation for Car Dumper
P & C Dock Co's Dock, Conneaut O

Fig. 21.

plant. The seventh day at one o'clock the 9000 tons of ore would have been taken from the holds of the vessels and loaded into 180 of the 50-ton steel cars, of which the Pittsburg, Bessemer and Lake Erie has 600 and is building 400 more. On the morning of the eighth day these cars would be delivered to the furnace at Bessemer or Duquesne, the four-stack furnace, having annual capacity of 800,000 gross tons of pig iron, at the latter point. The distance from Conneaut to this furnace is about 150 miles. On the ninth day, at seven o'clock in the morning, the ore would have run through the cupola and could be transferred to the Bessemer converter or mixer, and in less than an hour be turned into steel ingots. These ingots could be taken hot to the plate mill and made into ship plate in one hour; or if from the furnace the iron was made into pigs, some eight hours more would be required to make ingots of the pig. By the evening of the ninth day this plate would be ready for shipment. Even if twenty-four hours for delays are added, it is shown that in ten days ore from Lake Superior can be made into plate on a larger scale than in any other country in the world, and at considerably less cost."

THE PRESENT STATUS OF ENGINEERING KNOWLEDGE RESPECTING MASONRY CONSTRUCTION.*

By David Molitor, Mem. Am. Soc. C. E., Mem. Detroit Engineering Society.

I. INTRODUCTORY.

Masonry construction, in its relation to engineering, may be regarded as the origin from which the present science was evolved by a gradual progress of human research and experience. In the history of the world's advancement it constitutes a measure of the degree of civilization. It is older than the written history of any people; it ranks as the foremost instance in the adaptation of nature's forces and products to the uses and convenience of man; and, as an engineering subject it deserves the highest considerations, and gives birth to monumental works which, by their natural beauty and lasting qualities, stand as wonders of the world.

The volumes treating of the mechanics of engineering construction, or more particularly the subjects of earth pressure, retaining walls and masonry arches, constitute a very voluminous library. It would require many years of patient reading to review only the most important German, French, English and American productions. However, to infer from this, that our knowledge of the theories of masonry structures has advanced to a state commensurate to modern engineering science, is entirely erroneous. On the contrary, this vast mass of literature represents in reality an unceasing effort to determine a few complex natural laws by an endless series of mathematical speculations, based on a meager assortment of experimental data.

The truth of this assertion must be conceded when it is remembered that all of our theories on earth pressure are derived from miniature laboratory experiments, generally made with sand or grain, and under conditions vastly different from those found in nature. To within four years ago experiments relating to masonry arches were limited to a very few of almost insignificant character. As problems of this nature can be solved only by empirical methods, it is natural to conclude that the empirical laws found apply only within the scope of the experiments. Hence earth pressure and arch theories based on small laboratory tests are quite worthless when applied to full-size structures. Modern writers frequently treat of these subjects, but they advance nothing essentially new. Starting from the same erroneous assumptions employed by the old pioneers, they arrive at the same old conclusions, though the inter-

*Entered for copyright February 12, 1900.

mediate steps may be new and original. Hence such efforts do not represent real progress.

Much credit is due to the old theorists, among whom may be mentioned Coulomb, Poncelet, Scheffler, Culmann, Redtenbacher, Mohr, Considère, Winkler, Levi, Rankine, Weyrauch and many others. They have practically exhausted the subject as far as the meager experimental data available would warrant, and since the time of their investigations little or no progress has been made toward a satisfactory solution of the perplexing problem of earth pressure upon which the analysis of a large class of masonry structures depends.

Unlike the chaotic condition existing in regard to earth pressure theories, our knowledge of constructive details has steadily increased, and many modern masonry structures stand as monuments to engineering genius.

Despite the test of time which the numerous engineering stone structures of past ages have endured, it is nevertheless true that our modern high-grade masonry generally excels in quality and appearance the famous specimens of mediæval and ancient production. However, this is not generally true of the esthetic feature of modern designs.

Our modern, practical, improved methods of construction have never been excelled, or even equaled; and this feature in particular is entitled to even more credit as pertaining to engineering progress than would be a purely theoretical advancement.

While the pyramids of Egypt are still recognized as a "world wonder," yet the conditions under which they were produced, if known to us, would probably permit of their construction now as well as in ages past.

The wonderful improvements made in recent years in the manufacture of cements is undoubtedly responsible for much of the success attending modern achievements in masonry construction.

The elaborate arch tests, made in 1890-95 by the Austrian Society of Engineers and Architects, demonstrate that fixed arches may, within certain limits, be designed and constructed by the methods hitherto employed without incurring more error than is inherent in the nature of the problem, but the inference frequently drawn from these tests regarding the applicability and reliability of past theory and practice respecting long-span fixed masonry arches is somewhat erroneous. In fact, these experiments show conclusively that fixed masonry arches invariably fail by flexure, and not necessarily by compression; as under heavy loading the masonry breaks its continuity at the haunches and later at other points,

creating flexible or hinged joints; and failure finally occurs by a collapse of the masonry at the points so weakened.

In the light of these tests, therefore, it would seem proper to provide artificial hinges, thereby making the masonry arch susceptible to rigid analysis, permitting higher unit working stresses and obviating the danger of objectionable and often serious cracks generally occurring in large arches. This idea, after passing through various primitive stages in its development, finally resulted in the production of a perfect three-hinged masonry arch, of which type numerous masonry and concrete bridges have recently been erected in Germany. They have proven a success, and virtually mark a new era in masonry arch construction, as the introduction of hinges has removed the innumerable difficulties attending the computation and construction of large masonry arches.

In the following the subject is considered more in detail under separate headings:

2. EARTH PRESSURE THEORIES.

Theories in Common Use.

Classification of Theories. These may be divided into two principal classes:

First, those in which it is assumed that when the retaining wall of an earth bank fails, a prism of the supported earth severs its connection from the bank and slides on a plane surface called the surface of rupture. This is called the "theory of the prism of maximum pressure," originated by Coulomb, Poncelet and Scheffler, and was solved graphically by Professors Mohr and Karl von Ott.

The second class is founded on the theory of conjugate pressures. The differential equations, representing the equilibrium of a particle of earth in the interior of a mass, are applied to any point in this mass, and by integration the total resultant earth pressure is found. This theory, proposed by Rankine, Levi, Concidère, St. Venant, Winkler, Mohr and Weyrauch, is called "the theory of earth pressure in the indefinite mass." The graphical solutions of Professors Culmann, Scheffler, Karl von Ott, Winkler and Chas. E. Greene are based on this theory.

Assumptions. These theories are based on certain assumptions, and when applied to retaining walls give rise to contradictions which cannot be harmonized with facts observed in practice. While this is not surprising, especially when all the phases of the problem are considered together with the very limited experiments upon which the theories are based, yet it is very perplexing and often discouraging to the practicing engineer, who considers himself a

member of a learned profession, when he begins to realize his inability to solve what appears to be a most simple problem in engineering mechanics.

The assumptions are as follows: 1. That a certain kind of earth possesses a certain constant angle of repose. 2. That when an earth bank is artificially constructed with a slope exceeding the angle of repose for that material, a certain prism will sever its connection from the remaining earth and slide into a new position of equilibrium. This surface of separation, called "the plane of rupture," is assumed to be a plane surface. 3. That the resultant earth pressure exerted by such a sliding prism against the back of a retaining wall acts upon that wall in a direction which may vary between the limits of being parallel to the surface of the retained earth to making the angle of repose of the earth with the normal to the back of the wall. 4. That the resultant earth pressure has its point of application at a height above the base of the wall equal to one-third the height of the wall.

Accepting these assumptions, the plane of rupture and the resultant earth pressure become definite and determinable when the question of cohesion is neglected.

It will now be shown that these assumptions are all materially erroneous, approaching somewhat the truth for dry sand, but departing therefrom for other materials, such as common surface loam, clay, marl and mixtures of these with each other or with sand.

Angle of Repose and Surface of Rupture. To prove the fallacy of assumptions 1 and 2 it will be necessary to review the results of experiments on high embankments given in a paper on "Landslides," by the writer. (See JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, Vol. XIII, No. 1, January, 1894.) This subject will be taken up later, and only a passing reference here will suffice for the present purpose.

A sliding embankment, representing the actual conditions which obtain when earth is deposited at a steeper slope than is permissible, is shown in Fig. 1, where the material was Turneri clay. From this, and from a number of similar experiments for embankments of different heights, it was found that the angle of repose for the same material was not by any means a constant, but was an inverse function of the height of the fill. Also that the surface of rupture had no resemblance to a plane, but was practically an hyperbola in section. This fairly represents the disparity existing between results obtained from small laboratory experiments and actual cases as they occur in construction.

Direction of Pressure. The third assumption regarding the direction of the resultant earth pressure is probably nearer to the

facts than any of the others, though the following considerations are offered: According to Rankine and others this direction is parallel to the surface slope, and according to the majority of writers the resultant makes the angle of repose of the material with the normal to the back of the wall. The former theory is not rational, because the direction of motion of the sliding prism is not governed by the direction of the surface of the slope, but is largely dependent on the surface of rupture. The sliding prism glides on the surface of rupture, and the direction of motion will be parallel to that surface until the resistance of the wall changes this direction. When this occurs, then the direction of the resultant pressure must of course make the angle of repose with the normal to the back of the wall, but in the instant after rest is restored the direction of this pressure returns to its former position. It is readily understood that the pressure is a maximum when there is absolutely no motion, and that in the instant when motion occurs by partial giving way of a wall the pressure changes its direction and diminishes in intensity, thus relieving the wall of a portion of its burden and establishing a temporary state of rest.

Hence, in designing a wall the direction of pressure should be taken for the state of rest when the effect will be a maximum, as otherwise a motion is necessary to permit the earth to establish a frictional resistance with which to diminish its direct pressure against the back of the wall.

Point of Application. The fourth assumption, that the point of application of the resultant earth pressure is above the base of the wall by a distance equal to one-third the height of the wall, could be true only for a perfect liquid, in which the pressure increases with the depth below the surface and the distribution of pressure is represented by a triangle. Were the earth an inelastic solid, then the point of application of the resultant would be at half the height of the wall, and the pressure would be uniform and be represented by a rectangle. However, neither assumption is correct, but the two cases cited are the extreme limits; and, since earth is neither liquid nor solid, the point of application must be located somewhere between one-half and one-third the height of the wall above its base. Hence the pressure would be distributed according to some parabolic curve of the second or higher degree, with its vertex at the top of the wall.

The general condition being more nearly solid than liquid, the point is probably about 0.45 of the height of the wall above its base, varying between small limits, dependent on the amount of moisture contained in the earth. This is substantiated by a few experiments

made by a French engineer, Leygue, published in *Annales des Ponts et Chaussées*, 1885, II, p. 788.

Various Recent Theories.

Foremost among these may be mentioned the theory proposed in 1885 by the French engineer Leygue, previously referred to in this paper, and one by M. Chaudy, in *Memoires et Compte Rendu des Travaux de la Société des Ingenieurs Civiles,* December, 1895, discussed by G. C. Maconchy in *London Engineering* of August 26, 1898.

Leygue bases his theory on experiments performed by himself with sand and grain, from which he determines values for the empirical variable coefficient in the equation $E = c\,\frac{gh^2}{2}$, in which E is the horizontal component of the resultant earth pressure, g the weight of one cubic meter of material and h the height of the wall.

The theory of Chaudy results in the same equation, in which the empirical variable c is theoretically deduced.

All the older theories are based on this same equation, and hence the recent contributions just mentioned differ from them merely in the values assigned to this variable coefficient.

If earth, or earthy materials in general, were possessed with properties similar to water, in which friction between the particles is constant and differing only in degree for the case of liquids of different density and viscosity, then the above form of equation might be accepted as rational. However, it is a well-established fact that earthy materials retain their shape by virtue of frictional resistance combined with cohesion between the particles. Hence the law of equilibrium must of necessity differ widely from that observed for liquids, and in all probability the above equation is incorrect in form, which would explain the reason why none of the methods hitherto proposed are general in their application to all retaïning wall problems.

Leygue shows experimentally on a small scale that the point of application of the resultant thrust is at a point varying between 0.38h and 0.5h above the base of the wall. To this extent he has revealed a new fact which corresponds well with modern views. Chaudy still insists on having the point of application at $\frac{h}{3}$ above the base of the wall.

A rational theory of retaining walls (so called) was published by R. Iszkowski in *Oesterreich. Monatschr. für den öffentlichen Baudienst* of June, 1898. This theory is based on substitution of

a prism of masonry having a resisting moment to overturning equal to the moment of a triangular earth prism included between the slope of repose and a vertical plane through the crest of the slope of a given embankment. This slope of repose is supposed to be such a slope as would result by filling earth behind a vertical wall, which latter is suddenly removed, thus allowing the retained earth to establish a natural slope.

The fallacy of the argument is essentially in assuming that a prism of earth can exert an overturning moment about an edge, which is impossible. This can only be realized by a solid of sufficient strength to resist its weight on one edge, and even in the case of masonry such a point is found near one-third the base from the compressed edge. The data for determining the surface of repose is such as may be found in older text-books, and could not rationally be applied in the manner indicated by the author. The value of E is again a function of $\frac{gh^2}{2}$. The paper is interesting, but unfortunately does not increase our knowledge of the subject.

A New Theory of Earth Pressure.

General Remarks. The difficulty attending the evolution of a new theory of earth pressure may be appreciated by the fact that so little progress has been accomplished in the past twenty-five years, despite the many efforts made to advance our knowledge on this obscure branch of engineering science.

While the method proposed in the following may be open to criticism, yet it is thought to embody the most recent ideas and experimental data available. The method is not claimed to be perfect by any means, but, being based on facts which are not much in error, though at variance with previous assumptions, the best results attainable with the present status of our knowledge are expected therefrom.

The subject of earth pressure will not be definitely understood until some government or institution of learning shall spend a few thousand dollars on large experiments, as was done by the Austrian Society of Engineers and Architects in 1890-95 to solve the mystery of fixed arches. A satisfactory solution of this perplexing subject is considered attainable if the proper method is employed, and, viewed in this light, the neglect to undertake its solution must stand as a blemish on the profession. In the meantime the best available data must be utilized to the best advantage.

Before entering on this subject it will be necessary to abstract the results pertaining to the surface of rupture and angle of repose

as found from experiments by the writer, published in the JOURNAL OF ENGINEERING SOCIETIES, Vol. XIII, January, 1894. These experiments were incidental to construction work on the German Government railroad Weizen-Immendingen, a section of which was projected and built under the writer's charge in 1887-90.

The material consisted mostly of Opalinus and Turneri clays, of which about a half-million cubic meters were handled in the construction of railroad embankments, varying in height up to 18 meters. These banks were all constructed with $1\frac{1}{2}$ to 1 slopes, and in the course of a few months the material assumed a natural slope, which differed for embankments of different heights. In passing from the artificial to the natural slopes the material usually separated along a distinct plane of rupture, which, together with the final slope of rest, or surface of repose, was carefully measured. These aggravating mishaps, however, make up an extensive series of elaborate experiments, on which the new theory is based.

To increase the value of these experiments a description of the material used is here given.

Opalinus and Turneri clays are almost identical in appearance and in composition, and it would be difficult to distinguish between them were it not for the strata by which they are separated. The Opalinus clay, varying in vertical depth from 45-75 meters, is found in the lower Oölitic and immediately above the upper Liassic epoch. The Turneri clay, with a vertical depth of from 15-21 meters, is located in the middle Liassic, immediately above the strata of the lower Liassic. Both clays contain iron, and, when the atmosphere and water have not come in contact with them, they may be of a steel gray or blue color. The usual color, however, is brown, or that of ferric oxide, and the presence of a slight percentage of finely-divided silica causes them to glisten. In the natural state, whether blue or brown, these clays are very hard, almost slaty, but on being exposed to the atmosphere and water they disintegrate into a fine powder which when wet presents all possible properties objectionable to the engineer. The weight of a cubic meter of this clay in a naturally damp condition is about 1900 kilograms.

The angle of repose was found to be a variable depending on the height of the fill. The actual surface of repose is not a plane, but a curved surface, as shown in Fig. 1. However, for practical purposes an average plane was taken. From the various embankments which were constructed in Opalinus and Turneri clays, and from the numerous slides which occurred in this material, the following data (which are probably near enough to the facts for all practical purposes) were collected:

TABLE SHOWING RELATION BETWEEN H AND ρ, FOR OPALINUS AND TURNERI CLAYS.

Height of embankment H	0—2*m*	2—5*m*	5—10*m*	10—13*m*	13—15*m*	15—20*m*
Angle of repose ρ	45°0′	33°45′	26°40′	24°00′	22°00′	18°10′
Corresponding slope......	1 : 1	1½ : 1	2 : 1	2¼ : 1	2½ : 1	3 : 1
Tangent of ρ	1.00	0.66	0.50	0.44	0.40	0.33

Hence, for any given H the corresponding value of tang ρ may be taken from the above table.

As far as is known, this law applies to all materials, varying only in degree, being less marked for sand or sandy loam than for clay. However, no experiments on large sand embankments are at hand to verify this supposition.

The surface of rupture is not a plane, but a curved surface whose normal cross-section is an hyperbola, as is seen from the example shown in Fig. 1.

Fig. 1 represents a cross-section of a slide showing the proposed slope or original condition of the embankment, the actual surface of repose after the slide had established permanent conditions of equilibrium and the actual surface of rupture corresponding to this surface of repose.

Let A B C be a given embankment, which, by virtue of the steepness of the slope C B, slides into the position represented by the dotted curved line D E K. The sliding takes place on the *surface of rupture* D K. After complete equilibrium is established between the embankment and the moving mass, the surface line A B assumes the position D E while the slope line B C takes the irregular curve E K, *the actual surface of repose.*

The portion A D M, left standing, will have no influence on the sliding mass, and the level of the embankment is practically changed to D E. The depression from A B to D E could of course be filled up, and thus cause the masses to slide farther and to comply with the conditions imposed by the extra loading. The load A B D E would also drop to some new position intermediate between A B and D E, and after a number of repetitions of this process the conditions of the equilibrium for an embankment of height O A might be found; but this would lead to the same general law that obtained by assuming the portion A D M removed.

For practical and theoretical reasons, the actual curved surface of slope is assumed to be replaced by a plane N K. This will produce little or no difference in the results, and will conform with the usual manner of grading. The angle N K O, which the plane N K makes with the horizontal K O, is called ρ. This angle is found to vary with the height O D = H.

It was found from numerous slides that in this material (Opalinus and Turneri clays) the ratio $\frac{DN}{OD} = \frac{m}{H} = \frac{1}{3}$ nearly. Hence the distance

$$O\,K = L = m + \frac{H}{\tan.\rho} = H\left(\tfrac{1}{3} + \frac{1}{\tan\rho}\right) \qquad (1.)$$

Taking the horizontal line O K through the foot of the slope, and the vertical O D through the point of rupture D at the crown of the fill, as axes of co-ordinates, an equation representing the surface of rupture may then be found.

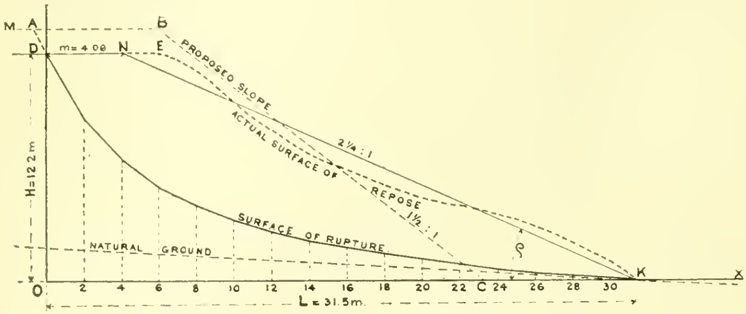


Fig. 1

Assuming the curve to be an hyperbola whose ȧsymtotic axes are parallel to the axes O K and O D, its equation must be of the form

$$(x + a)\ (y + b) = c \qquad (2.)$$

where a and b are the perpendicular off-sets between the asymtotes and the axes O K and O D, and c is a constant depending on the eccentricity of the curve.

Taking the co-ordinates of the curve D K from the figure, substituting these in the above equation (2), then solving, from each successive three equations, for a, b and c, and averaging these results, values are obtained which may be substituted in equation (2).

It is found, from numerous curves of rupture and for various heights H, that these constants bear the following approximate relations to H and ρ, or, indirectly, to L, since $L = H\left(\frac{1}{3} + \frac{1}{\tan.\rho}\right)$.

$$a = \frac{L}{5},\ b = \frac{H}{5},\ \text{therefore}\ c = \frac{6HL}{25} = 6\,a\,b \qquad (3.)$$

Solving the above equation (2) for y, and substituting from equation (3) for c — ab, its value 5ab,

$$y = \frac{5ab - bx}{a + x} = \frac{H(L - x)}{L - 5x} \qquad (4.)$$

TABLE OF COMPARISON OF OBSERVED AND COMPUTED VALUES OF y FOR DIAGRAM IN FIG. 1.

Assumed x.....	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	31.5
Observed y.....	12.2	9.0	6.7	5.3	4.2	3.2	2.7	2.2	1.8	1.4	1.1	0.9	0.7	0.5	0.3	0.2	0.0
Computed y....	12 2	8.7	6.6	5.1	4.1	3.3	2.7	2.1	1.8	1.4	1.1	0.9	0.6	0.4	0.3	0.14	0.0

The curve of rupture may then be plotted for any case in question, provided H and ρ are given.

The above conclusions seem to apply to most other materials, except as to the degree of curvature of the surface of rupture, which for sand would approach a plane surface, as is indicated by small experiments, although not much reliance can be placed on any such conclusions unless they are based on the actual behavior of large masses of sand, for which no experiments have as yet been made.

Time is also an important factor in deciding on what actually takes place when a mass of earth is deposited for the purpose of obtaining its angle of repose. It may require six or eight months for a slope to change from its original to its stable condition, and if the difference between the two is but slight it may require years. In the latter case it may take place by gradual settlement without showing sudden motion.

It will be observed that the term "angle of repose" is here used to signify the natural slope which a certain material acquires when exposed to the elements, and hence is dependent on the friction and cohesion existing between particles of earth. The term as commonly understood applies to friction between particles of loose, dry earth without cohesion.

The conditions of equilibrium for a certain mass of earth, as determined experimentally, are illustrated in Fig. 1. Accordingly, any load imposed on the top of the embankment along D E or on the slope near E, will disturb the equilibrium of the sliding prism, and will cause the latter to move to a new position of rest. Also any additional mass placed on the slope near the point K will hinder sliding. Hence, in the nature of the case, the sliding prism, as determined in the preceding, represents the limiting case of equilibrium resulting from the balance between gravity forces and internal friction and cohesion of the material.

Therefore, the sliding prism D N K in its limiting condition of rest, exerts a tendency down the surface of rupture D K just equal to the maximum resistance t, which the underlying earth is able to offer against sliding along this surface of rupture; therefore, any additional material added to the prism D N K will cause an increased tendency down the surface D K, which cannot be balanced by the resistance t, and motion will ensue.

This frictional and cohesive resistance t, when determined, will represent the maximum total resistance which can be exerted on any mass of earth between the foot of the slope K and the top of the bank at N; and any material in excess of the prism D N K will exert a downward tendency on the surface D K, which must be resisted by a wall at K.

To determine the frictional resistance t, necessary to hold in equilibrium the prism D N K, it is necessary to find the resultant tendency of this prism down the surface D K for the limiting case of equilibrium. (See Fig. 2, in which a section of unit thickness is considered.)

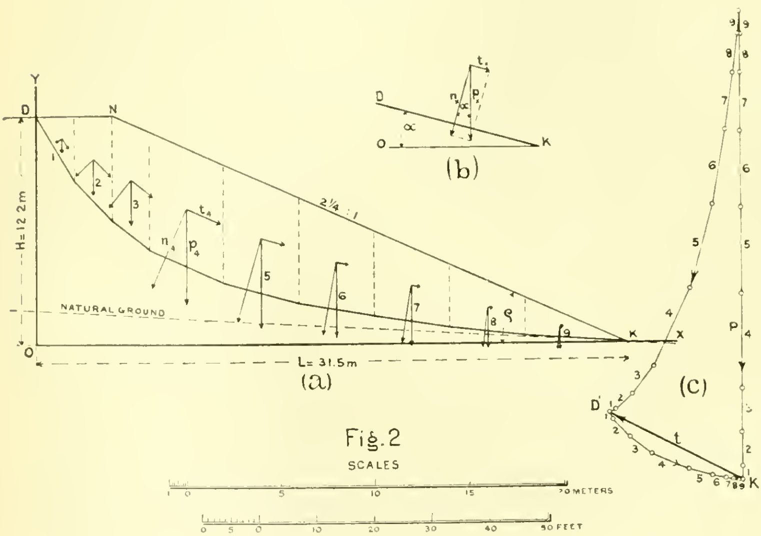


Fig. 2

If the area of the sliding prism D N K be divided vertically into laminæ or sections, then the weight p_x of each section will have a component t_x parallel to the surface of rupture immediately below the section and another component n_x normal to this surface. In the limiting condition of equilibrium this parallel or tangential component t_x representing the downward tendency on an inclined plane, Fig. 2 b, must be exactly balanced by the frictional and cohesive resistance existing along the surface of rupture D K. This is true only in the limiting case. Hence the resultant of all the tangential forces along the surface of rupture will represent the downward tendency of the sliding prism. This resultant must be equal and opposite to the resistance t, which latter is found graphically in Fig. 2 c.

To find the earth pressure on the back of a retaining wall, Fig. 3, it is necessary only to determine the downward tendency T of the sliding prism D S V K on the surface D K, in the manner indicated for finding the frictional resistance t, then knowing the direction and magnitude of t and T, they may be made to form a triangle in which the resultant earth pressure E is the unbalanced force, Fig. 3 b.

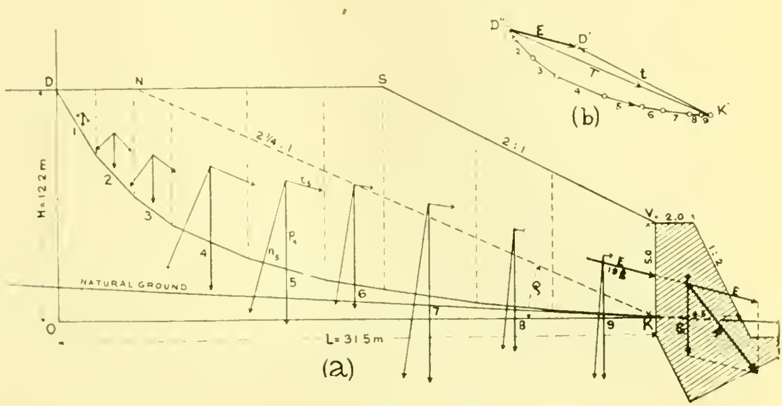


Fig. 3.

Hence, the direction and magnitude of the resultant earth pressure are found directly, and its point of application is taken at 0.45 K V above the point K, in accordance with the previous discussion.

Another problem, without surcharge, is solved in Fig. 4, where the earth pressure is also found graphically by the method given by Professor Karl von Ott, in which the area of the shaded triangle in square meters, multiplied by the weight of one cubic meter of the material ($g = 1900$ kilograms), gives the resultant earth pressure acting at $\frac{KV}{3}$ above K. For this solution $E^1 = 21.7g$, agreeing closely with the result found by the new method except as to point of application.

In all of the above solutions it is advisable to use areas only instead of actual weights; and in finding the opposing moment offered by the masonry wall, the area of the wall is multiplied by $\frac{g^1}{g}$ to reduce to equivalent mass of earth. In the above this ratio was taken at 1.16 by assuming $g^1 = 2200$ kilograms for masonry.

The direction of the earth pressure as found bears no relation to the direction of the back of the wall, and this is as it should be, giving the most unfavorable condition. However, the resultant thrust in being resisted by the wall must necessarily be deflected in

the instant when motion occurs either of the earth or the wall, but whenever a perfect state of rest obtains then the thrust probably returns to its original direction of maximum effect.

A Probable Future Solution.

From the above it is seen that the older theories are based on assumptions which are largely erroneous, and, while the truth may be more closely approximated in the light of recent experiments and ideas, yet no theory has as yet been formulated which may be regarded as perfect. Therefore, the time has come when a less speculative and more accurate method would be highly appreciated.

The simplest problem of a retaining wall, mathematically treated, leads to quite complicated equations, and in general the graphical treatment is far more satisfactory, being more readily adapted to complex cases and affording a better check and insight into the otherwise obscure analytical methods. For this reason more success may in future be expected from a graphical treatment.

However, to reach a satisfactory solution, the nature of the materials involved, the many variable conditions affecting their behavior, and the prime importance of the subject demand far more than mere mathematical investigation. The only promising solution will probably consist in an experimental or deductive determination of the actual pressure found on the back of a wall under various conditions.

It may seem vain to attempt the exact determination of a function depending on such variable material as earth, yet for a given kind of earth in a given state of moisture a definite law certainly exists, and this law once determined for different conditions of the same earth would enable the engineer to treat the problem intelligently and to estimate the probable error of his assumptions. This is by no means possible at the present status of our knowledge.

While the problem is not considered beyond the possibility of solution, the only reason for a failure to accomplish this end has been a lack of funds and a well-developed plan of carrying on experiments. All engineering structures should be so designed as to comply with the most unfavorable conditions which may at any time occur consistent with economical requirements, and this in itself is sufficient reason why experiments and investigations should be made under correspondingly unfavorable circumstances.

Of all the experiments made, or to be made, those only are valuable which are conducted under the actual conditions existing in nature, and of these the extreme cases are most valuable in leading to proper conclusions.

Experiments performed on dry earth or sand are of little or no value, since nature always supplies a certain amount of moisture, which at times may increase to the limits of saturation, thus vastly altering the characteristics of the material.

The effect produced by moisture on earth, or sand, has been ascertained to be about as follows: The specific gravity increases with moisture; the friction between the particles is a maximum for the dry state and diminishes with increased moisture, becoming almost nil for the state of saturation; the cohesion is increased for a slight degree of moisture, but is diminished for a further increase and is nearly destroyed for the case of saturation. The earth pressure generally increases for increased moisture and becomes a maximum for the saturated condition, which latter may, however, be prevented by supplying proper drainage to the back filling.

It seems proper here to suggest a method for the successful solution of the problem of earth pressure which at present constitutes the most deficient branch of engineering science. As was said before, this may be expected only from an elaborate series of experiments to be conducted on a plan something as follows:

A very rigid wall should be constructed about 20 feet high and perhaps 100 feet long, with good foundation, on level ground. In a vertical section near the central portion of this wall a series of pressure gauges should be placed so as to communicate the earth pressure to indicators on the front of the wall. These pressure gauges would require special design in order that they may fulfill all the necessary requirements. The pressure surface might then be covered with a flexible oiled canvas to prevent the earth from squeezing in between the gauges and the masonry.

The pressure exerted by a fill, placed back of this wall, could now be observed for an extended period of time under various conditions of moisture, etc., and when all desirable measurements were made the material could be removed and another kind of earth used to continue the experiments. This should be repeated until the variety of material used and the different heights employed would cover the subject in a general way.

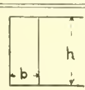
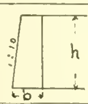
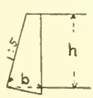
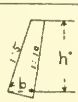
The funds for such experiments could probably be obtained through an appropriation from the national or state government, or from the National Society of Civil Engineers, and the work could be best performed under the direction of some large institution of learning. It is needless to mention the value which such an investigation would have for the profession at large, and the engineering students participating in the work would gain a very valuable experience.

3. DESIGN AND CONSTRUCTION OF RETAINING WALLS.

Without attempting to enter into the details of computation involved in ascertaining the stability of retaining walls, and which may be found in books on masonry construction, so far as theory is applicable to the subject, it is intended here to consider more particularly the economic features of design in connection with practical considerations by which safety and durability in construction may be attained.

Economy in Design. In considering a wall of given cross-section the stability is attained by a certain necessary mass of masonry which, by its resistance to overturning, must sustain the pressure of the retained earth. The quantity of masonry necessary to fulfill this requirement is, however, entirely dependent on the manner in which the mass of masonry is distributed over the section. That is, a certain earth pressure may be sustained with equal safety by walls in which the quantity of masonry employed may differ by 100 per cent., representing comparative economy in design.

The important effect of the shape of a wall on economy of material is clearly illustrated by the following table, in which certain relative dimensions have been worked out for different batters according to Rankine's theory by Professor E. Haeseler. In each case the back filling is assumed level with the top of the wall, and the angle of repose of the material is taken as 33°. The bottom

No. of section	Section	$g = g'$ and $\rho = 33°$		$g' = 1.25g$ and $\rho = 33°$	
		$b = f(h)$	$A = f(h^2)$.	$b = f(h)$.	$A = f(h^2)$.
1		0.350	0.350	0.320	0,320
2		0.327	0.277	0.300	0 250
3		0.307	0.222	0.287	0.198
4		0.238	0.199	0.215	0.174
5		0.472	0.372	0.456	0.356

width of the wall, b, as also the area of cross-section, A, are expressed as functions of the height of the wall, h.

This table, which is quite useful in taking off preliminary values, shows that section No. 4 is most economical, while No. 5 is least so. The effect which the shape of the cross-section bears to the economy in amount of masonry required is also illustrated by the two solutions given in Figs. 3 and 4.

From the above it is seen that the most economical form (local conditions permitting) would be one in which the wall is battered towards the retained earth with a batter just sufficient to retain the center of gravity of the section within the base of the wall; this limit being desirable for safety during construction, though if care is exercised the batter may be increased somewhat beyond this limit.

Provisions to Insure Safety and Durability of Retaining Walls. These are applied in accordance with the causes of failure, which will be briefly discussed before treating of necessary remedies for their prevention.

In computing the stability of a wall it is customary to choose a section in which the resultant of the earth pressure and the weight of the wall shall remain within the middle third of the wall, thus striving to prevent any tensile stresses in the masonry. The entire question of stability is, however, based on the assumption that the foundation is perfectly rigid, which it never is except when bedrock is available. The yielding of the foundation is one of the most frequent causes of failure, hence the apparent necessity of the greatest precautions on these lines. Besides giving rise to local settlement in the alignment, a faulty foundation usually results in failure by partial or complete overturning of the wall.

Overturning may occur even on good foundations, and is then the result of poor drainage of the back filled material or scanty dimensions or poor masonry.

There are few, if any, long retaining walls which are free from vertical cracks, which latter may result from local settlement, excessive pressure or wide changes in temperature. The nature of the cracks will generally disclose their cause. A vertical crack of uniform width is usually the result of temperature stresses. A vertical crack, wide near the ground, gradually diminishing in width and disappearing at the top of the wall, is invariably the result of local settlement. Horizontal cracks are of rare occurrence, except in combination with vertical cracks, and generally have little significance. Changes in alignment always indicate overturning, and usually accompany settlement. It is scarcely necessary to add that any or all of these causes may at times manifest themselves in a single effect, making a diagnosis more or less difficult.

When a retaining wall is founded on anything other than bed-rock it is advisable to widen the base of the foundation masonry as indicated in Figs. 3 and 4, so as to bring the resultant thrust R well within the central portion of the base. In doubtful cases the base may be widened sufficiently to allow the thrust to pass through its center.

Great care must be exercised in back filling a newly completed wall, since at this time the mortar is less capable of resisting stress than at any future time when the cement has become thoroughly set. Also, loosely deposited earth, possessing little cohesion in this state, exerts a greater pressure than when well compacted. Hence the back filling should not be applied until the mortar is well set, and then the former should be deposited in successive layers, each of which should be well rammed.

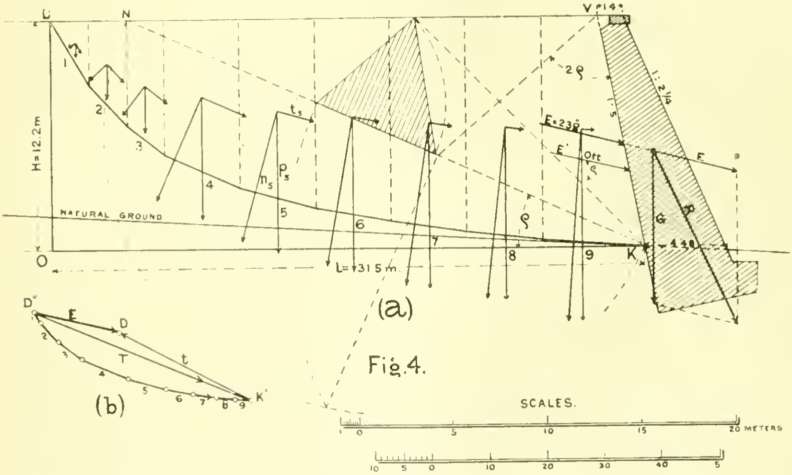


Fig. 4.

As moisture always accumulates in the back filling, it is essential that proper drainage be provided adjacent to the wall, otherwise a condition of saturation may follow which would increase the earth pressure to its maximum value $\frac{gh^2}{2}$. This is about twice the pressure which any wall is usually designed to carry, and will almost invariably prove disastrous.

The best and cheapest way to establish drainage is to provide a masonry gutter along the back of the wall at the lowest level suitable for draining either through the wall (by leaving openings at intervals) or at the ends of the wall; preferably the former. From this longitudinal gutter a dry rubble backing of 1 to 3 feet in thickness should be carried to near the top of the masonry, thus inter-

cepting all seepage and completely draining the back filling. In severe cases numerous rubble-filled gutters may be extended into the back filling at right angles to the main wall. This is one of the most important precautions necessary in retaining wall construction.

To prevent vertical cracks from temperature effects in long walls it is desirable to insert vertical expansion joints at intervals of 30 to 50 feet. These joints should be so constructed as not to weaken the resisting power of the wall, which is accomplished by making the joints dovetailed in plan. No such provision is commonly made, and the results are apparent when it is added that the linear coefficient of expansion of masonry ranges between one-fifth to one-third that of steel.

Cracks resulting from temperature effects should never be closed by filling in cement mortar unless it is found that they do not close in summer after long-continued warm weather, in which case they were probably caused by shrinkage in joints, and may then be filled.

A retaining wall which shows signs of overturning may generally be strengthened by the construction of buttresses placed at intervals commensurate with the case in hand, provided there is sufficient clearance in front of the wall to permit of this. A new wall may show indications of trouble, and if supported by timber braces for a time sufficient to allow the back filling to settle and cohere in itself, the wall may become perfectly safe.

What has been said in the above regarding failures in walls applies generally to wing-walls, masonry culverts and abutments.

A new style of retaining wall might be employed with advantage, especially where a good foundation is not available.

The writer has frequently considered the advisability of constructing a wall of concrete and old railroad iron in such a manner as to make the back filling assist in producing the stability against overturning. (See Fig. 5.)

The earth pressure is resisted by the wall A B acting as a beam in cross-bending, being internally stiffened by old iron rails or similar material embedded crosswise in the concrete near the outer or tension face of the wall. Stability is established by the rails G K acting as tie-rods and held by the concrete base C D, which in turn is loaded with the retained earth. To take up the stress existing along B C D, the base C D is connected with the wall by occasional columns of concrete.

So far as known, this idea has never been carried out, and it may deserve consideration in certain cases where local conditions are favorable to its application.

4. FIXED MASONRY ARCHES.

General Considerations.

The fixed arch, as distinguished from the hinged arch, belongs to the class of indeterminate structures in which the abutment reactions cannot be expressed in terms of the external forces without involving the elastic properties of the arch material.

In applying the theory of flexure to material like masonry, considerable doubt may justly be expressed as to the reliability of results obtained. However, the extensive arch tests conducted by the Austrian Society of Engineers and Architects from 1890 to 1895, have demonstrated very conclusively that stone, brick and concrete arches follow the laws of elasticity, and the application of the theory of elasticity to such structures would seem perfectly justified in the light of these experiments.

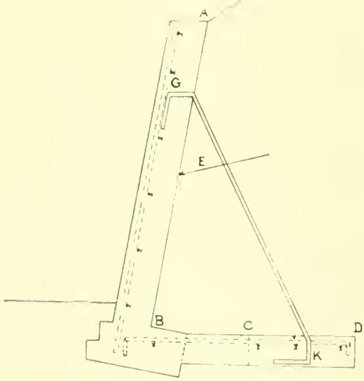


Fig. 5.

Past experience has shown that only very low unit stresses are allowable in fixed masonry arches, a fact which proves beyond doubt that such arches are not adapted to very economical utilization of material. The reason for this is apparent. The initial stresses in portions of an arch, resulting from distortions and abutment displacements during and after construction, may often attain dangerous values, leaving only a small fraction of the breaking strength for a working stress. Fortunately, a partial failure of a portion of an arch under excessive stress caused by distortions has the tendency to readjust the distribution of stress by changing the shape

to one better adapted to the strained condition. This is the reason why such distortions rarely become dangerous, but the fact illustrates the extent to which any theory is applicable to fixed masonry arches without using a large factor of safety, varying from ten to twenty. Without this large uncertainty, resulting entirely from the rigid construction, high unit stresses of one-tenth to one-sixth, the ultimate strength of the material, might safely be employed.

Since masonry is not well adapted to withstand tension, no tensile stresses are allowed in arches. To accomplish this the resultant thrust at any normal arch section must lie within the middle third of such section. This follows from Navier's theory for distribution of stress on a voussoir joint.

Hence, for a given span and load, the arch ring must possess a definite shape, requiring a very delicate adjustment of the line of thrust within the middle third of the arch ring.

Metal arches are independent of this requirement, since the actual stresses arising from a certain loading and shape of arch can always be provided for when the dead load has been approximately assumed.

In designing a masonry arch the shape, dimensions and weight must be known, or assumed; and if the resulting stresses exceed the allowable limits, then any or all of the assumed values must be altered until by a succession of approximations the proper shape and dimensions are found. This is a long and tedious process, especially when the more accurate methods are employed.

According to the recommendations of the Austrian Society of Engineers and Architects, as a result of their elaborate tests, a fixed masonry arch should be constructed only when the following conditions can be realized:

1. The abutments must be perfectly rigid.

2. The false work must retain its form during the period of construction of the arch ring.

3. The masonry must be of the best quality.

4. The construction of the arch ring must be most carefully conducted.

5. The false work must not be released until the mortar has thoroughly set.

6. When the false work is released, it must be done gradually and uniformly.

These conditions, except the two first named, can always be fulfilled, though the lack of rigidity of abutments and false work are the two great obstacles in the way of long span, fixed, masonry arches.

Arch Theories.

Historical. The earliest theoretical treatment of arches is ascribed to de la Hire, who, in 1712, advanced the theory that an arch acted as a wedge in which the central or crown portion had the tendency to slide between the quarters adjacent to the abutments. Eytelwein, in 1808, applied this theory to individual arch joints, and made allowance for friction.

The combined action of shear and bending was first recognized by Coulomb in 1773, and this theory assumes that an arch may fail either by one portion sliding on another or by a joint opening as the result of bending. Experiments made by Boistard in 1808, proved that failures were to be expected only by cross-breaking, and not as a result of shearing action.

Coulomb's theory was improved by Audoy (1820), Lamé and Clapeyron (1823), Navier (1826) and Mery (1827), and was graphically treated by Poncelet in 1835.

The analogy between the arch and suspension bridge, from which the theory of the line of thrust was evolved, was first established by Gerstner in 1831. This theory was improved and adapted to practice by Hagen (1844), Bauernfeind (1846), Schwedler (1859), Heinzerling (1869), von Ott (1870), Ritter (1876) and Wittmann (1878).

The theory of elastic deformation was introduced by Navier in 1826, by his analysis of the stresses on an arch section, in which he assumes a combined thrust and bending moment distributed over the section. This theory was supported by experiments of Bauschinger and Koepke. Winkler (1867) and Belpaire (1877) apply this theory to the elastic arch, and the more recent modifications by Engesser, Ott, Mueller-Breslau, Melan, Weyrauch and others are now generally accepted as the most reliable arch theories. They differ from each other only in methods of solution and degree of approximation. All are based on the same assumptions, and the derivation of the formulæ are essentially alike; but, owing to the extremely complicated equations resulting from the theory, different authors have neglected certain terms supposed to be of insignificant value, while others, especially Melan, and Weyrauch, attempt a rigid solution which is very complicated. The treatment of this subject by modern English and American writers is essentially according to Ott and Melan.

The graphical solution in general use is based on the most probable position of the line of thrust in a given arch ring for a given case of loading.

The theory of elasticity leading up to a purely analytical solution is more reliable, though far more complicated in its application.

The comparative accuracy and reliability of these two methods will be discussed in the following:

The theories in common use are two in number. First, *the line of thrust theory,* which is generally employed, and depends on an assumed, most probable position of the line of thrust within the arch ring; and, second, *the theory of elastic deformation,* by which the statically indeterminate abutment reactions are found by the application of the theory of flexure. The method of solution by the first theory is purely graphical, and by the second theory it is purely analytical, and does not necessitate finding the line of thrust, though this line is definite and determinable by the method. The second method may be made semi-graphical by the introduction of influence lines, which are very serviceable when dealing with concentrated moving loads.

To give a clearer idea of the distinctive features of these two theories it will be necessary to show the general relations existing between the external or applied forces and the internal stresses in a fixed arch. (See Fig. 6.)

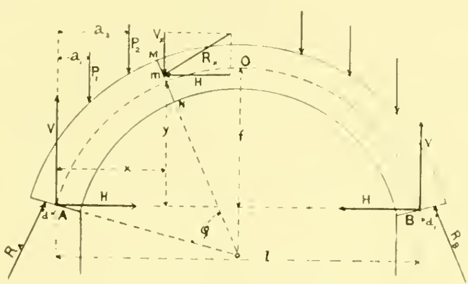


Fig. 6.

The arch A O B supports the loads P_1, P_2, etc., producing reactions R_A and R_B. The reaction R_A can be replaced by a horizontal component H and a vertical component V acting at the point A, and a moment $R_A\ d = M$ about A. Also R_B can be replaced by H and V^1 acting at B, and a moment $R_B\ d_1 = M^1$. Hence V and V^1 are the vertical abutment reactions, H is the constant horizontal thrust and M and M^1 are the abutment moments.

By taking center of moments about B and A, the respective values V and V^1 can be found thus:

$$V = \frac{1}{l}\left[M^1 - M + \Sigma_0^l P(l - a)\right] \qquad (1.)$$

$$V^1 = \frac{1}{l}\left[M - M^1 + \Sigma_0^l Pa\right] \qquad (2.)$$

For any section M N having co-ordinates x and y, the shear V_x, bending moment M_x and resultant thrust R_x, are as follows:

$$V_x = V - \Sigma_0^x P \tag{3.}$$

$$M_x = M + Vx - Hy - \Sigma_0^x P\,(x - a) \tag{4.}$$

$$R_x = \sqrt{V_x^2 + H^2} \tag{5.}$$

$$N_x = V_x \sin.\varphi + H \cos.\varphi = \text{thrust normal to the section} \tag{6.}$$

From N_x and M_x the stresses on the extreme fibres of the section M N may be found from

$$f = \frac{N_x}{F} \pm \frac{M_x}{W} \tag{7.}$$

in which F is the area of the arch section M N, and W is the moment of resistance of this section.

It is readily seen that the determination of unit stresses resulting from any system of loading involves the terms M, M^1 and H, which cannot be determined from purely statical considerations.

According to the theory of elastic deformation, these unknown factors are determined from the elastic properties of the material, while in the older graphical solution they are merely approximated by assigning certain assumed conditions to be fulfilled by the line of thrust.

Hence the theory of elastic deformation fixes the position of the line of thrust in terms of the elasticity of the material, while according to the graphical solution an infinite number of lines of thrust may be constructed for the same arch and same loading, and it becomes a question to decide which of all the possible lines is the most probable.

Hagen (1862), according to his "theory of the most favorable distribution of stress," defines the most probable line of thrust as one for which the vertical projections of the minimum distances, between the line of thrust and the edges of the arch ring, become equal. Culmann (1866) designates this most probable line as the one which approaches most nearly to the arch center line in such a manner that the pressure at the most critical points becomes a minimum. Winkler defines the most probable line as the one for which the areas inclosed between the line of thrust and the arch center line are equally divided according to the method of least squares. Generally a problem is considered solved when, for a given span and load, a line of thrust is found which falls entirely within the middle third of the arch ring. This is, however, very far from constituting an acceptable solution, as will presently be shown. Plausible proofs for all the above assumptions have long been sought, but have never been found.

The graphical method is, at best, nothing more than the application of the principles of the three-hinged arch to fixed arches, in which the location of the hinged points is arbitrarily assumed at the crown and springing. A line of thrust passed through these three points must remain within the middle third of the arch ring. If these points are assumed on the arch center line, then M and M^1 become zero, and H is determined as for a three-hinged arch. While all this is constantly done, there is nothing to justify the procedure.

The derivation of the formulæ for M, M^1 and H is considered foreign to the purpose of this paper, and is, therefore, omitted.

It is now proposed to show the comparative value of the two methods of solution of fixed arches and their reliability, as found from the experiments of the Austrian Society of Engineers and Architects.

Reliability of the Methods in Common Use. The graphical method, as was just stated, assumes that the real or most probable line of thrust is the one for which the highest pressures at the critical points become a minimum. Hence every line of thrust must either be the most probable line or else it is one which is less favorable than the most probable line. But, if only one line of thrust is possible for a given allowable stress on the extreme fiber at the critical points, then, if the structure is to be regarded safe for all time, this line must continue to exist when the material increases in strength (as by setting of the cement), or when the arch undergoes slight elastic or permanent deformations. For this there is absolutely no assurance, though it is an essential necessity in the general assumption.

It is also a matter of great uncertainty to know when any line of thrust really is the most probable line, since this depends on a more or less arbitrary definition, the requirements of which are fulfilled by a series of approximations.

From these and other considerations it follows that this method is neither reliable nor scientific. If arches designed by this method have stood well it is most probably due to the extremely high factor of safety generally employed, and not to the reliability of the method.

The analytical method, based on the theory of elasticity, is certainly scientific, though its value depends largely on experimental verification.

A sandstone masonry arch, of 23 meters span and 4.6 meters rise, was tested to destruction by the Austrian Society of Engineers and Architects. The breaking load was 3218 kilograms per square

meter on the half arch. For this load the formulæ of Professor Weyrauch give a maximum ultimate compressive resistance at failure of 33 atmospheres. The sandstone had a compressive strength of 770 atmospheres, and the cement mortar 311 atmospheres. Samples of mortar taken from the arch after destruction broke under a pressure of 80 atmospheres. The compressive strength of the masonry must, therefore, have been about 400 atmospheres, or over twelve times the actual strength developed by the arch.

The results obtained from the tests on a brick arch and a Moniér arch, of practically the same dimensions as the sandstone arch, are similar to those just cited.

While it is not fair to expect very reliable results from the application of the theory of elasticity to material stressed to the point of rupture, yet the error incurred would probably not exceed 100 per cent., which would not begin to explain the still existing disparity in the above results.

It seems quite likely, however, that a very high initial stress existed in the arch as a consequence of the changes in shape of the arch ring, resulting from the shrinkage of the mortar joints by the setting process of the cement after the mortar had attained sufficient strength to sustain the partial dead load imposed prior to removal of the centers.

If this supposition is justifiable, then it follows that though the theory may be correct and perfectly applicable within the limits of elastic deformation, yet the large factor of uncertainty resulting from permanent distortions, which must always be expected in fixed arches, necessitates a high factor of safety in addition to a very thorough mathematical investigation, if reliable results are expected.

While the theory of elasticity is undoubtedly the only trustworthy basis for the analysis of fixed arches, and should always be employed in designing structures of any importance, it does not follow that the older graphical method of investigation and many of the empirical rules in common use are all worthless. On the contrary, the preliminary design can be carried out most efficiently by the aid of the simpler methods, and the final design may then be tested by the application of the more accurate method.

It is thus seen that the theory of fixed arches has reached a status of perfection quite in keeping with the nature of the problem, the still existing uncertainty being a function of the material and other circumstances, depending on the rigidity of the abutment foundations, conditions of erection, etc., all of which can never be entirely eliminated.

The above applies only to arches for which the loading is known with considerable accuracy. For arches sustaining high earth banks the loading cannot be determined with any great degree of certainty. Hence the design of such structures is less definite, though the elastic property of the superimposed earth assists greatly in distributing pressure and rendering conditions more favorable to their safety.

The methods employed to obviate excessive stresses in fixed masonry arches will now be discussed.

If it were possible to build an arch ring in such manner that its line of thrust would pass through the center of the ring at the crown and haunches at the time of releasing the false work, a large proportion of the indeterminate stress could be prevented. In other words, the bending moments at the critical points would then be almost zero for symmetrical loading, reserving the strength for the unsymmetrical live load and other contingencies affecting the shape of the arch ring.

In the ordinary process of construction the arch ring is commenced at the haunches and the load gradually applied to the false work, thus distorting the latter and causing bending stresses in the completed parts of the ring. The final settling of the ring, produced by the contraction of the mortar joints as a result of compression and shrinkage during the setting process of the cement, even when the abutments remain perfectly rigid, is often sufficient to create serious initial stresses, thus destroying to a large extent the usefulness of the structure.

Several methods have been used, with more or less success, to relieve an arch of undue initial stress during construction.

One of the oldest of these is to set the arch stones on the entire false work, spacing the joints by inserting small strips of wood, and lastly filling all the joints simultaneously with mortar. This is still a very good program for erection, but it is not very well adapted to large structures, owing to the excessive stresses produced in the false work, and frequently causing considerable settlement in the entire arch ring. This can, however, be prevented by wedging up the false work just previous to filling the joints.

Another method frequently employed in the construction of brick and concrete arches is to close a complete ring adjacent to the false work, and, after allowing the mortar or concrete to set, the remainder of the arch is constructed and the total load is carried by the first ring rather than by the false work. By this means the settlement during construction is very slight, but, as is readily seen, the intrados is excessively stressed, a condition which cannot be averted and which is highly objectionable.

A program of construction frequently used on large arches necessitates commencing work simultaneously at two, four or six points of the ring and closing at three, five or seven points, respectively. The longer the span the greater the number of points of commencement.

The most modern method consists in the introduction of temporary flexible or hinged joints at the crown and haunches, and following the previous program of construction. These flexible joints are made of stone with curved, roller-like surfaces; or iron blocks may be used, forcing the line of thrust through the center of the arch ring at the crown and haunches during the period of construction. These open joints are filled with cement mortar either before or after removing the false work. Sheet lead has also been used for this purpose by inserting narrow strips into the crown and springing joints, allowing just sufficient surface of contact on the arch center line to carry the pressure without causing the lead to flow. The open joints are afterwards filled with good mortar.

This last mentioned method gives very good results in preventing cracks and excessive settlement during construction, but subsequent changes cannot be compensated for, which is the only obstacle still remaining in this class of structure. Eventual settlements in foundation masonry; contraction of mortar by evaporation of water used in mixing the same; compression of mortar joints from loading; elastic deformations caused by temperature and load effects; all these are ever present to create stresses which, in spite of all precautions during construction, may attain dangerous proportions and make it utterly impossible to estimate the actual ultimate strength of a fixed masonry arch.

It should be remembered that for masonry arches the live load is generally only a small fraction of the dead load, and for this reason an arch which is sufficiently strong to sustain its own weight permanently will carry temporary live loads with perfect safety. When initial stresses attain breaking limits the masonry generally chips near the surface, thus relieving the stress and allowing the line of thrust to return to a more favorable position. In this way an arch which has become distorted may readjust itself to a new condition of stress.

In conclusion, it might be well to recall the recommendations proposed by the Austrian Society of Engineers and Architects, which, if strictly carried out, would limit the adaptation of fixed masonry arches to comparatively short spans and bedrock foundations, as these recommendations require the fulfillment of the following conditions:

1. The abutments must be perfectly rigid.

2. The false work must retain its form during the period of construction of the arch ring.

3. The masonry must be of the best quality.

4. The construction of the arch ring must be most carefully conducted.

5. The false work must not be released until the mortar has thoroughly set.

6. When the false work is released, it must be done gradually and uniformly.

The use of sand jacks or sand pots, which was introduced in 1854, during the construction of the Austerlitz Bridge in Paris, offers a very novel and efficient means of releasing the false work supports.

The necessity of these recommendations is clearly understood after what has been said regarding the theory of fixed masonry arches and its application to practice.

The first two conditions can only be realized when rock foundations are available, and when the false work is made rigid by very substantial foundations. The other requirements can generally be fulfilled by exercising proper care, and by permitting only good material and workmanship.

5. THREE-HINGED MASONRY ARCHES.

The extent to which theory is applicable to fixed masonry arches has been adequately demonstrated in the previous.

To obviate the difficulties and prevent the uncertainty shown to exist in fixed arches, the introduction of hinged joints at the crown and haunches may be regarded as a most welcome innovation; first applied bv Koepke, of Dresden, in 1880, by providing curved, open, voussoir joints in the arch ring at the crown and haunches. In 1885 Karl von Laibbrand, of Stuttgart, substituted sheet lead for the open joints, and in 1893 applied cast iron hinged bearings.

The three-hinged arch is free from initial stresses, otherwise resulting in fixed arches after releasing the false work. Small abutment displacements and changes in temperature do not affect the magnitude or distribution of stress in the arch ring, and hence do not cause cracks.

This form of arch admits of a rigid analytical treatment. For this reason the allowable working stresses may be chosen much higher than for fixed arches; they may range from one-tenth to one-quarter the ultimate strength of the masonry without sacrific-

ing safety or durability. The strict requirement regarding the rigidity of abutments and false work, so very essential to fixed arches, is a matter of comparative insignificance, provided the abutment foundations are safe.

Therefore, the three-hinged arch is especially well adapted to the economic construction of long-span bridges, and, being free from the numerous objections inherent in the fixed arch, is well adapted to conditions where only moderately good foundations are available.

The introduction of hinges has placed the masonry arch on a high plane of engineering perfection, and has removed its restricted application, thus materially enlarging the field of usefulness so justly belonging to this most substantial, economic and esthetic form of bridge construction.

No disadvantages have as yet developed from the use of hinges, and none are likely to develop. Numerous bridges of this type, of spans ranging from 10 to 50 meters, have been constructed in Germany and Switzerland within the past fifteen years. All are giving excellent satisfaction.

Therefore, owing to its economy, permanence, low cost of maintenance and esthetic features, the three-hinged masonry arch is destined to become a successful competitor of iron and steel bridges in all cases where the natural conditions of foundations and length of span do not offer unsurmountable difficulties.

This subject has been exhaustively treated in a paper read by the writer before the American Society of Civil Engineers. (See Vol. XL, 1898, Trans. Am. Soc. C. E.).

6. CONCRETE AND IRON ARCHES.

This comparatively new system of construction, introduced about twelve years ago in France and Germany, is fast displacing the solid masonry structures of the past.

The desirability of combining concrete with steel or iron evidently arises from the widely different properties of concrete under compressive and tensile stress. The compressive strength being about ten times the tensile strength (so far as our present knowledge of concrete would indicate), makes it impossible to use concrete with economy. In fact, common practice has always been to use concrete and masonry only under compressive stress. By supplying tensile strength to those parts of a structure where tensile stress occurs, by the insertion of steel or iron rods, the combined material becomes more widely applicable, and is susceptible to a more economic utilization.

The various systems of concrete and iron arches (mostly patented) may be summarized as follows: The Moniér, the Wuensch, the Moeller and the Melan. There may be others, but they probably involve no new principles.

The Moniér patent is so broad, embracing in a general way any iron parts enveloped by cement, that it is difficult to understand why not all other systems are infringements. However, this system as generally employed consists of a series of iron rods imbedded in the concrete near the surfaces of the intrados and extrados to supply the required tensile strength. The rods extend longitudinally from one abutment to the other, and are tied together at intervals by wire. Expanded metal has been used in a similar manner.

The Wuensch system employs only longitudinal angle irons or tees, placed near the intrados and extrados of the arch or beam, relying on the concrete to perform the functions of a web system.

System Moeller amounts to nothing more than a very flat concrete arch with a metal tie-rod to take up the horizontal thrust. The tie-rod is anchored directly in the concrete of the arch abutments.

The Melan system inserts concrete arches between iron I beam or latticed arches. It is, therefore, a succession of parallel metal and concrete arches in the same span.

The combinations of concrete with iron or steel offer a great many advantages in practical and economic construction, though the application is perhaps too recent to warrant a definite conclusion regarding the lasting qualities of these composite structures. It must also be admitted that the theories of this class of structure are still very primitive.

Moniér arches are generally designed for a constant modulus of elasticity,

$$E = E_0 \left[1 + \frac{I_1 (E_1 - E_0)}{I \, E_0} \right]$$

in which E_0 = modulus of elasticity of concrete; E_1 = modulus of elasticity of iron; I = moment of inertia of the combined concrete and iron section, and I_1 = moment of inertia of the iron section alone. This is based on the assumption that the two materials in acting together must undergo the same elastic distortions.

Arches built according to Wuensch are designed to carry the total maximum load entirely by the concrete, and the unsymmetrical live load entirely by the metal parts. This is a somewhat arbitrary method.

The Moeller system probably admits of the most exact design,

and is especially well adapted to floor arches and light bridges. There is nothing about the design which would require special consideration.

The Melan arch being a combination of arches of different materials, makes it difficult to determine the proportion of the total load carried by each material. However, since the elastic deformation of an arch is approximately proportional to the quantity $\frac{1}{E\,I}$, and two arches if they would work together must undergo the same deflection, it follows that the load must be divided in proportion to the products E I for each material, or that

$$\frac{\text{Load carried by the concrete arch}}{\text{Load carried by the iron arch}} = \frac{E_0\,I_0}{E_1\,I_1}$$

in which E_0 and I_0 apply to the concrete section and E_1 and I_1 to the iron section. This may be far from the truth, though it has generally given good results compared with tests.

Regarding the durability of concrete and iron structures, we are not in a position to say definitely what the probabilities are. However, with the exception of the Melan system, the iron section is generally quite small, and even a slight corrosion might prove disastrous, because so much depends on the iron parts. It is quite likely that moisture might penetrate some of the hair-like fissures generally found in masonry and concrete, which would do mischief in the course of time. Roebling found such corrosion on some of the outer strands of the anchorage cables of the Niagara and Brooklyn Bridges, where the cables had been imbedded in concrete.

The widely different physical properties of concrete and iron do not seem to offer any serious obstacles, as was at first predicted; at least, none have developed during past experience. Concrete appears to possess an adhesive strength with iron which is equal to, or even greater, than the tensile strength of the former; the coefficients of expansion are nearly enough equal in the two materials to offer no serious objections, and by a proper distribution of loads their elastic properties may be so harmonized as to make them work fairly well together.

Meanwhile many new structures of this type are being constructed, and time alone will suffice to clear up the still existing doubts. So much may, however, be predicted that it is not unlikely that some of the very keen Moniér arches, depending so largely on the slender iron network for their strength, are apt to prove unsatisfactory in point of durability. Melan and Moeller arches will probably be longer lived.

7. CONCRETE.

Concrete has become one of our most important materials of construction, and a few remarks may be appropriate in concluding this paper.

This material, universally used in compression, has been wonderfully improved in recent years by the general introduction of high-grade cements, though our knowledge of the properties of concrete under compressive stress is rather meager, and much valuable work still remains to be done towards increasing our present supply of reliable experimental data.

Among the most desirable experiments to be made the following might be mentioned: The determination of the shrinkage of concrete of different mixtures while setting from time of placing same till it has reached various ages; the permanent set which concrete undergoes under various compressive stresses; the modulus of elasticity at various ages for different mixtures, and, lastly, the compressive strength of cubes corresponding to mixtures used for the above experiments.

Such work would be highly valuable, and interesting as well. Those wishing to take up this subject may find some valuable suggestions in a paper by the writer on "The Properties of Concrete under Compressive Stress," published in the JOURNAL OF ENGINEERING SOCIETIES for May, 1898.

TEMPORARY BRIDGE ACROSS THE MISSISSIPPI RIVER, AT ST. PAUL, MINNESOTA. MOVING OF THREE 140-FOOT SPANS.

By A. W. Munster, Member of the Civil Engineer Society of St. Paul.

[Paper presented to the Society December 4, 1899.*]

The reconstruction of the old part of the Wabasha street bridge across the Mississippi River at St. Paul, Minn., required the building of about 700 linear feet of temporary bridge over the south arm of the river to carry the traffic during the construction period of one year.

Fig. 1.

This temporary structure was located 50 feet downstream from, and parallel to, the bridge line for a length of 420 feet across the river-arm; the remaining portion being curved land approaches, connecting at the north end with the spans across the main channel of the river (rebuilt in 1889), and at the south end with an embankment in continuation of South Wabasha street.

The spans in the old structure, for the length covered by this temporary bridge, consisted of four spans of 140 feet and one of

*Manuscript received January 22, 1900.—Secretary, Ass'n of Eng. Socs.

FIG. 2.

FIG. 3.

112 feet. The most economical and satisfactory procedure was to utilize three of the four 140-foot spans, by moving them the required distance to timber piers constructed for their support at properly located points in the line of the temporary bridge. This gave an unobstructed waterway; and, by leaving the old piers in position until next summer, the timber piers will be protected from drifting logs and ice.

This work was completed in November last. The approaches at each end are supported on trestle-bents of common type, and the piers for the spans are constructed as braced trestle-towers supported on piles.

Fig. 4.

The accompanying photographs show so clearly their construction, and the manner in which the spans were moved, that very little additional explanation is necessary. The distance between the faces of the old and new piers is about 30 feet, and this space was bridged with four 15-inch I beams bolted together with separators, and supported midway by a trestle-bent on piles. Four beams of the same section, bolted together in a similar manner, formed the support from bridge-seat to bridge-seat on the timber piers, and four 6-inch I beams, on blocking, made a track for the passage of

the shoe across the old masonry piers. The ends of the 15-inch I beams rested on the top of masonry and timber piers respectively, and the spans were first lifted vertically to bring the bottom of the shoe above the top of the I beams. Plates $\frac{3}{8}$ inch in thickness were placed, one under each shoe, and connected together with an angle strut, and loose 1-inch rollers were placed between these plates and the I beams. The spans were moved with a 2-inch screw about 6

FIG. 5.

feet in length, connected, through removable iron links, to the $\frac{3}{8}$-inch plate under the pilot-shoe, and operated by a system of hand-cranks and cogwheels in a frame fastened to the top of the I beams.

The time used in moving each of these spans was about eight hours, and the work was accomplished without hitch or accident of any kind.

The plans of operation were devised jointly by the contractor, Mr. W. S. Hewitt, of Minneapolis, and the writer.

PROGRESS OF DRAINAGE IN NEW ORLEANS.

By Alfred Francis Theard, A.M.C.E., Member Louisiana Engineering Society.

[Read before the Society October 9, 1899.*]

In view of the partial completion of one section of the drainage system in this city, I have thought that a careful study of the general plan as recommended in the report of the Advisory Board of Engineers would prove interesting; and the object of this paper is to explain the general features of this plan as to its several sections, and to show how far it has been carried out as to the section now nearly completed.

The essential factors for solving any drainage problem are:

First. The topography of the territory to be drained.

Second. Hydrography; the quantity of water to be taken care of.

Third. The available means, if any, of removing this water.

These three factors divide the subject into three branches, and can be made to include all of its details.

First. Topography includes conditions of the entire territory; the permeability of its surface, conditions as to navigation and improvement, existing or future.

Second. Hydrography includes the amount of rainfall to be cared for; the rate of precipitation, its duration, its usual area, its actual run-off; the daily seepage; the daily quantity of water to be disposed of outside of rain water.

Third. The available means of obtaining drainage; that is, the existing system, if any; the location of the outfalls.

For the information of those who are not familiar with the report of the Advisory Board on the drainage of New Orleans, 1895, in which all of these subjects are fully described, I will try, as briefly as possible, to explain what these factors are in this city.

The territory upon which the city of New Orleans is built has an area of 24,932 acres, on both the left and right banks of the Mississippi River, within levees. It has an elevation of 33 to 20 feet, Cairo Datum; this slope occurring within 6000 to 9000 feet of the river banks, leaving a large surface practically level, with an elevation of about 21 Cairo Datum, or some 18 feet below the high water of the Mississippi River and some 4 feet below that of Lake Pontchartrain; or, as the mean elevation of the Gulf is 21.26 Cairo Datum, never at any time above the level of the surrounding bodies of water. Six thousand acres of this territory are

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improved, being paved or covered by buildings; the remaining portion is composed of farms, gardens, suburban lands or swamps. All of this territory is now surrounded by levees, the elevation of which is 41 Cairo Datum on the river front and 27 Cairo Datum along the upper and lower boundary lines, the lake front and navigation canals.

Information as to rainfall was obtained by means of self-registering rain gauges distributed at six different points in the city. These gauges, which are still in operation, give the total rainfall, its duration and its time, and can be checked by actual measurement with a graduated stick. In charge of attentive observers, they have given very satisfactory and valuable results.

From these observations, in my opinion, it can be safely concluded that the average annual rainfall is 55 inches; that it is principally made up of short showers, lasting from five to twenty minutes, yielding a maximum total precipitation of 1 inch per shower, and that the rate of precipitation has been often as high as 6 inches, and once as high as 7 inches, per hour.

The run-off from these rains has been carefully computed, both as to slope of territory (from 3 feet per thousand, as a maximum in the improved portion, to almost a level in the unimproved sections), as to the natural permeability of the soil (which will become greater as the moisture line is reduced), as to the amount which is collected by the roofs of buildings, cisterns, tanks, etc., in the improved section and as to the evaporation, in this hot climate, of a percentage of that portion which naturally remains over the undrained and unimproved section.

The result of these computations has been embodied in a diagram of run-off curves annexed to the report above mentioned, and has been found of such interest that all recent publications on the subject of run-off have treated of and reproduced it. Gaugings covering a period of over one year at each of the old draining machines showed the marvelous result that for a rainfall of two hours' duration it took nearly seventy-two hours to pump 52 per cent. of the total precipitation.

The daily flow, or amount of water which will reach the drainage canals in dry weather, was, from actual observations made during a dry spell of forty-one days, accurately established. This quantity, of course, can be considered as constant, because, while it will be considerably lessened by the inauguration of a sewerage system, it will be increased by the natural growth of population and the development of the improved section.

As to the outfalls, one can easily decide as to which should be selected between the Mississippi River, Lake Pontchartrain and

Lake Borgne. Lake Borgne was recommended by the advisory engineers. Its selection avoids the pollution of Lake Pontchartrain by drainage water, and affords an advantage in its proximity to the Gulf. As to the river, it would be far too expensive to raise the water over the levees, and all advantages derived from the natural fall of the surface to be drained would be lost.

The adopted plan provides for a main canal leading through the entire area, and to which the canals and drains of the several sections are tributary. This canal was located in about the lowest part of the city, thus affording the best opportunity for using natural fall. Beginning at the intersection of Nashville avenue and Claiborne street, it runs in a northeasterly direction along Broad street to St. Bernard avenue; thence in an easterly direction to Lafayette avenue; thence along Florida avenue to Jordan avenue, where pumping station No. 5 is located. The main outfall begins at this point; runs in a northeasterly direction to Bayou Bienvenu; this waterway connecting it with Lake Borgne. The plateau or level basin, through which the main canal is located, and the recognized fact that it is unsafe and very expensive to excavate in this soil at a greater depth than 15 feet below the surface, made it necessary to establish stations, at equal distances along the main canal, for the purpose of lifting the water, to give it artificially the slope which cannot be obtained naturally by the topography. It was also desirable, because of the difference in area of the several sections and of peculiar difference in the intensity of storms over these areas, to provide a separate and distinct service for the several sections.

For the above purposes the five pumping stations were located along the main canal, each giving full service to the section by the number of which it is designated and at the same time lifting the water to obtain a sufficient head for a calculated velocity through the main canal. Thus Melpomene pumping station, No. 1, receives all drainage from Section No. 1, and St. Louis pumping station, No. 2, Bernard pumping station, No. 3, Lafayette pumping station, No. 4, and Jourdan pumping station, No. 5, give the same service for Sections Nos. 2, 3, 4 and 5 respectively. Algiers pumping station, while of a different type, gives the same service to the Algiers section.

The water in the several sections is carried to the pumping stations by branch canals, drains and branch drains; all of which are located so as to afford immediate relief to the several localities which they are to drain in so far as can be done with the existing grades now used for the surface drainage, and all are so graded as to provide for future connections with an underground system. By this I mean that as a canal is built it is arranged to connect, by

a system of temporary catch-basins at street intersections, with existing gutters, and will in such a way give relief; but as a street is improved the old system of gutters will be dispensed with and a modern underground system will connect directly with the drainage canal.

The adopted plan divides the city into six drainage sections entirely independent and distinct; each served by a complete system of its own; all to be connected by a main canal, thereby affording opportunity to build at any one time so much of the system as the means at the disposition of the city will permit. The territorial limits were so fixed as to provide improved drainage adapted to present as well as to future conditions: increased population, more crowded buildings, paving of streets more extended and impervious.

Each section is provided with a complete system located advantageously both as to surface slopes, extent, shape and character of the locality. The natural depressions throughout the city determined the location of several canals. For instance, Lake Borgne being conceded as the best outfall, and the natural fall being from the ridge and the river bank towards Broad street, the logical location of the main canal was along that stretch of territory, the lowest of the entire city, ranging in elevation from 19 to 21.5 feet Cairo Datum.

For a full illustration of the location of the several drainage canals, drains, branch drains, pumping stations, relief canals, outfalls, etc., and the relative position of the several sections, I have prepared the accompanying map, and for further information I beg to refer you to the report on the drainage of New Orleans (1895) already mentioned. In it will be found a full description of the adopted plan.

The following, quoted from the report, gives the order of importance for the extension of the several parts of the work:

"That part of the second section lying between Broad street and the river, on account of the concentration there of improved properties, paved streets and business houses, and of its central position with reference to the most densely inhabited area of the city, is now (1895) more urgently in need of improved drainage than other localities, and it is evident that the benefits to be derived from the extension of the plan would be of greater immediate public value there than in any other section of the city."

This recommendation includes:

First. The construction of pumping stations Nos. 2 and 7, and the relief branch canal connecting these stations.

Second. The construction of St. Louis canal.

Third. The Basin street, Canal street, Camp street, Chartres street, Julia street, Constance street, Claiborne street and Galvez street drains.

Fourth. The improvement of street grades and gutters.

Fifth. The improvement of Orleans relief outfall (giving a relief outlet to Lake Pontchartrain).

Sixth. The construction of the Hagan avenue, Carrollton avenue, Murat, Banks, Taylor and Conti streets open canals.

Seventh. The construction of the main canal and its connections with the sections above and below.

Says the report:

"The work in other sections may be prosecuted in any order or at any time as it may be found most convenient. Whatever is done towards carrying out the plan in any section cannot be injurious to the interests of other sections, whether or not they are directly benefited.

"The first section has the largest area, and at present its tendency towards increase in population and improvement is probably more apparent than that of the other sections.

"The work in the Algiers section, on account of its comparatively small size and cost, might be done with less means than would suffice for much effective work in other sections, and hence might be undertaken at an early date.

"In the third, fourth and fifth sections the situation and conditions are so similar as to offer at this time no suggestion of priority in date or of limit in which work should be undertaken."

Let us now consider what has been done so far to carry out the recommendations of the advisory engineers and the adopted plan.

Pursuant to an order issued by the State Legislature, requesting that the Louque cut, which connected the Melpomene outfall with the New Orleans navigation canal, be closed, the initial step of the Drainage Commission was to award a contract, November 27, 1896, for the digging of a canal to connect the Melpomene canal with the upper protection canal. Thus, compelled by legislation to devote their attention to the first section, it was decided, with the advice of the Chief Engineer, that the proposed canal should form part of the ultimate system. Hence its location on Seventeenth or Palmetto and North Line streets to the upper protection canal. It forms part of the relief canal between pumping stations Nos. 1 and 6, is 6300 feet long, 56 to 80 feet wide and about 14 feet deep, with side slopes of $1\frac{1}{2}$ to 1, and has a level bottom at elevation 8 feet Cairo Datum. Total cost, $53,000.

Upon organizing, and assuming charge of all funds available,

the Drainage Commission decided, upon the advice of the Chief Engineer, to carry out as much of the recommendation of the Advisory Board as the funds at hand would permit. The question whether electricity or steam should be used as a motive power to operate the several stations to be eventually constructed was then discussed, and it was decided to refer this to an expert electrician, who would, in conjunction with the Chief Engineer, examine into the relative cost of building and operating an electric power plant. It was decided, pending this decision, to take alternate bids to afford comparison as to the cost of steam and electric operation.

On July 8, 1897, bids were opened for the construction of the following:

Contract "A." Central electric power station, St. Louis pumping station, No. 2, Orleans pumping station, No. 7, and (because of the construction of the Seventeenth street canal) Metairie pumping station, No. 6.

Contract "B" (alternate for Contract "A" without central electric station). Pumping stations Nos. 2, 6 and 7 for steam operation.

Contract "C." Lined and covered canals,—viz, St. Louis canal, Basin street canal, Julia street canal, Constance street canal, Canal street canal, Chartres street canal, Camp street canal, Claiborne street canal and Galvez street canal.

Contract "D." Open and unlined canals,—viz, Orleans relief canal, Orleans relief outfall and Metairie outfall.

The report of the expert and of the Chief Engineer, based upon information gathered from a tour of inspection through the principal Northern cities, and also upon a comparison of the bids submitted for the construction of an electric plant for the operation of the several stations, proved decidedly favorable to electricity as a motive power. Thus the bids for Contracts "A," "C" and "D" were accepted; the contract for this work was signed on August 9, 1897, and work was immediately started.

Considering the nature of this work, now nearly completed, the ability with which it was planned and executed speaks for itself. Allow me, however, to state here that it is a most extraordinary occurrence, and a most unnatural one in our city, that work of such magnitude could have been carried on to completion without a single appreciable interruption caused by complaints of residents, interference from courts, injunctions, etc., and without any serious accidents. This has been a source of gratification for those connected with this work, and I think speaks very highly of the work itself.

LINED AND COVERED CANALS.

The several canals which I shall briefly describe, and which are included in Contract "C," just above mentioned, are lined with sides of masonry. These retaining walls have a thickness of 1½ to 2½ brick at the flood line, 3½ to 6½ brick at the bottom; the thickness of the walls being regulated by the depth and width of the canals, and vary in height from 3 feet 6 inches to 6 feet 0 inches. They are on concrete bottoms 1 foot 3 inches to 2 feet 6 inches in thickness, and for all the larger canals on a double row of 40-foot piles, 4 x 8-foot centers, with 12 x 12-inch caps. All the lined canals are covered with brick arches supported by I beams, 7 to 20 inches in depth, all 4 feet 0 inches centers, with a cover of a thick layer of concrete having a thickness over center of arches of 1 to 4 inches.

The St. Louis canal extends from Basin to Broad street, along St. Louis street. It is 5600 feet long, 20 to 25 feet wide at the flood line, 8.2 to 8.7 feet deep and has a fall of 3.6 feet in the total distance. Cost, including $60,000 of asphalt pavement, $407,000.

The Basin street canal extends along Basin street from Julia to St. Louis street, is 4950 feet long, 13 to 20 feet wide, 6.6 to 8.2 feet deep and has a fall of 4.1 feet in the total distance. Cost, $181,000.

The Julia street canal extends from Constance to Basin street, along the upper side of Julia street; is 2800 feet long, 8 feet 4 inches to 11 feet wide, 5.4 to 6.2 feet deep and has a fall of 4.7 feet in the total distance. Cost, $75,000.

The Constance street canal extends from Howard to Julia street, on the river side of Constance street; is 960 feet long, 6 feet 0 inches to 8 feet 4 inches wide, 4 to 4.9 feet deep and has a total fall of 2.6 feet. Cost, $17,000.

The Canal street canal extends from Chartres to Basin street, on the north side of Canal street; is 2100 feet long, 9 feet to 9 feet 8 inches wide, 6 to 7.5 feet deep and has a total fall of 4.5 feet. Cost, $68,000.

The Chartres street canal extends on the lake side of Chartres street from St. Louis street to Canal street; is 1450 feet long, 5 to 6 feet wide, 3.5 to 4.8 feet deep and has a total fall of 4.3 feet. Cost, $26,000.

The Lower Camp street canal extends from Poydras to Canal street, along the river side of Camp street; is 1296 feet long, 5 to 6 feet wide, 3.5 to 5.3 feet deep and has a fall of 4.1 feet. Cost, $16,000.

The Upper Camp street canal extends from Girod to Julia

street; is 560 feet long, 5 feet wide, 3.1 to 3.9 feet deep and has a fall of 1.9 feet. This canal is on the river side of Camp street. Cost, $8000.

The Claiborne street canal extends along the center of Claiborne street, from Julia to St. Louis street; is 5016 feet long, 5 feet to 10 feet 6 inches wide, 3.8 to 7.9 feet deep and has a fall of 6.3 feet. Cost (estimated), $90,000.

The Galvez street canal extends along the center of Galvez street, from Julia to St. Louis street; is 5000 feet long, 5 feet to 12 feet 6 inches wide, 5 to 6 feet deep and has a fall of 2.7 feet. Cost (estimated), $110,000.

PUMPING STATIONS.

St. Louis pumping station, No. 2, is located at the intersection of Broad and St. Louis streets. The building covers an area of 5000 square feet. It receives all the water collected by the system of canals on the river side of Broad street, in the second drainage section, and pumps it, for the present, by way of Orleans relief canal towards pumping station No. 7. In addition to this, upon the completion of the main canal, it will receive all the drainage from the first drainage section and pump it down Broad street towards pumping station No. 3. In the future, in times of excessive storms, its discharge by way of the Orleans relief canal can be used. Total cost, including suction and discharge basins, $135,000.

Orleans pumping station, No. 7, is located at the intersection of Taylor avenue and Orleans street, near the New Orleans and Western Railroad crossing. It covers an area of 5000 square feet, exclusive of the suction and discharge basins. Its duties are, for the present, to pump all the drainage water of the second section, delivered from pumping station No. 2, by way of the Orleans relief canal, to Lake Pontchartrain, through the Orleans outfall. In the future, during heavy storms, after the first wash from the streets has been directed towards the ultimate outfall, it will give additional relief by discharging some of the accumulated storm water, by way of the Orleans relief outfall, into Lake Pontchartrain. Total cost, including basins, $175,000.

Metairie pumping station, No. 6, is located at the intersection of the New Orleans and Western Railroad and the upper protection canal. Its model and dimensions are similar to those of pumping station No. 7, and its duties are the same for the first drainage section as are those of pumping station No. 7 for the second section. Total cost, including basins, $175,000.

The Central electric power station is built at the intersection of

the New Orleans and Western Railroad and the New Orleans and Northeastern Railroad, fronting on Florida avenue, and very near the corner of Lafayette avenue. The building covers an area of 25,000 square feet. It has a separate boiler room and an electric plant. It was so arranged as to allow a partial equipment of boilers and electric plant for the present requirements of the drainage system, reserving additional room for a complete installation when the system is completed. The electric plant is of the most improved design, and one of the finest in the South. Total cost, including installation for present requirements and line for transmission of power to pumping stations Nos. 2, 6 and 7, $350,000.

In speaking of the power plant and pumping stations I have restricted myself to generalities, as a full description of their machinery, foundations and of all details of their construction and operation could not be comprehensively included in this paper.

I should very much desire, at some future meeting of this Society, to listen to a paper on this subject, which could no doubt be made very interesting when explained by one more competent than myself.

OPEN AND UNLINED CANALS.

The Orleans relief canal extends along the line of the old outfall, from pumping station No. 2 to pumping station No. 7. It is an earth canal, 12,000 feet long, 34 to 80 feet wide at the surface, with side slopes of from $1\frac{1}{4}$ to $1\frac{1}{2}$ to 1 and a level bottom throughout at 8 feet Cairo Datum. Cost, $70,000.

The Orleans relief outfall is the old Orleans canal. It is 10,000 feet long, about 60 feet wide and 10 feet deep. Cost of cleaning and widening, $10,000.

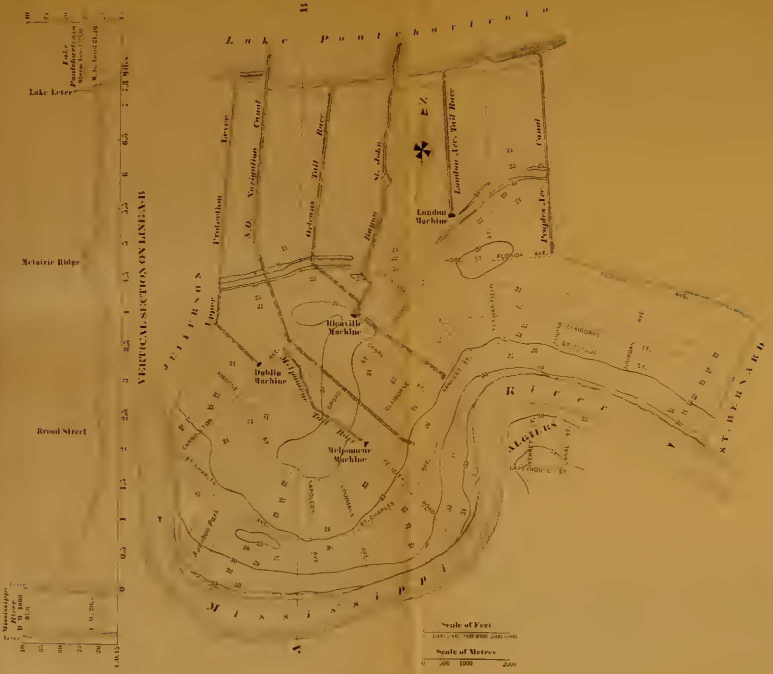
The Metairie relief, or upper protection outfall, extends from pumping station No. 6 to the lake shore. It is 50 to 65 feet wide, 12 feet deep and 13,000 feet long. Cost of cleaning and widening, $4000.

The Metairie relief canal, or rather that portion of it which connects the Seventeenth street canal with pumping station No. 6, is 3700 feet long, with side slopes of $1\frac{1}{2}$ to 1, and a level bottom at elevation 8 Cairo Datum. Cost, $11,000.

The Dublin and Claiborne canals, from Seventeenth street along Dublin to Claiborne street, and along Claiborne or Mobile street to Nashville avenue, were also cleaned and reshaped. Cost, $13,000.

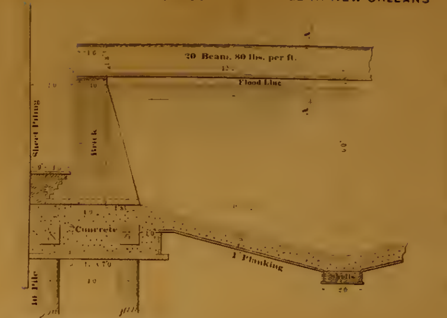
The above-named work on open canals was made by means of floating dredge.

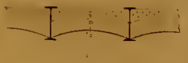
On October 21, 1897, four months after letting the above-



Contour Map of New Orleans.

Map of New Orleans, Showing Proposed Drainage System.

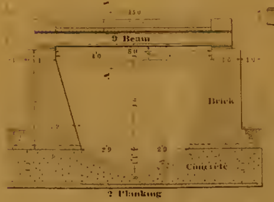




Section at A-A

Section of St. Louis St. Canal at Sta. 17—00.

Section at A-A



Section of Smaller Drainage Canal.

mentioned contracts, the Drainage Commission decided to give some relief to the section in the vicinity of the Jourdan avenue pumping station, thereby claiming from overflow a large tract forming the rear of the fifth drainage section. The Jourdan avenue canal was ordered built. It extends from St. Claude street to Florida avenue; is 6266 feet long, 33 to 42 feet wide, with side slopes of 1¼ to 1, 12.4 to 13.5 feet deep and has a fall of 2.3 feet. Total cost, $30,000.

On July 21, 1898, owing to the benefit derived by the residents of the district from the inauguration of the Jourdan avenue canal, and the presence of the dredge in the vicinity offering an inducement to secure additional work at reduced prices, the Florida and Lafayette avenue canals were put under contract.

Florida avenue canal forms part of the main canal. It extends from Elysian Fields avenue to the Lafayette avenue pumping station; is 4300 feet long, 50 feet wide and 11 to 12 feet deep, with side slopes of 1½ to 1.

Lafayette avenue canal extends from Claiborne street to Florida avenue on Lafayette avenue; is 4342 feet long, 35 feet wide and 8 to 12 feet deep, and has a fall of 4 feet. Cost of the two canals last named, $19,000.

Thus the fourth and fifth drainage sections were benefited, but this at the detriment of the farmers along the Louisville and Nashville Railroad between Peoples avenue and Lee Station, because the water collected by the Jourdan avenue system was, at the Jourdan avenue pump, lifted over the rear levee and there left to find its own way into the lake. This caused the letting of the main outfall. It extends from Jourdan avenue pumping station, No. 5, to Bayou Bienvenu; is 11,000 feet long (including that part of the bayou which is widened), 60 feet wide and 10 feet deep. Estimated total cost, including levees, $25,000.

In addition to all of the work above named, a contract was given for the cleaning of the Eliza and Lapeyrouse canals, in the Algiers section, and of several earth canals in the central, fourth and fifth sections. This was intended to give relief until such time as more permanent work should replace these earth canals. The total cost of this work was $14,000.

The following contracts were awarded during July, 1899:

Contract "E." Melpomene pumping station, No. 1, at Broad and Melpomene streets. It will give the first section the same service as pumping station No. 2 gives to the second section.

Contract "F." Third street canal, from St. Charles avenue to Claiborne street; and St. Charles street branches, from Toledano to Felicity street. These canals will be lined and covered.

Contract "G." The Claiborne and Melpomene canals, from Third street to pumping station No. 1, thence to Carrollton avenue and Seventeenth street, thus completing the connection between pumping stations Nos. 1 and 6.

Contract "H." Algiers pumping station building, removing one set of boilers from Jourdan avenue station, furnishing one pump at Algiers station and installing necessary pole line and motors, etc., to operate Jourdan avenue pump by electricity furnished by the central plant.

Work on the last five contracts has merely been started, and should be completed within one year.

From the preceding *résumé* of what has been accomplished with the limited resources of the Drainage Commission it is evident that all work so far completed or contracted for has been a step forward in the right direction for the construction of a complete drainage system in accordance with the plan recommended by the Advisory Board of Engineers in 1895.

It was a happy occurrence for our city, and most eminently proper, that the two distinguished engineers selected to design and execute this great work, one as the Chief Engineer of the Drainage Commission and the other as the engineer of the contracting company that secured the bulk of the work, had participated so actively in preparing this plan during their connection with the Advisory Board. This insured a thorough familiarity with all of its details and purposes, and a most perfect design and execution.

I have refrained from further description of the canals and stations for the obvious reason that each, in my opinion, could be made the subject of an interesting study, and any attempt to go into details would have been an imposition on your kind attention.

I have gathered the information imparted herein largely from the report of the advisory engineers, which I have often quoted, and from the records of the Drainage Commission, to which I, as an humble assistant, have personally contributed.

Through the courtesy of the Chief Engineer of the Drainage Commission, and with his permission, I have prepared the following drawings here exhibited:

First. Contour map and profile.

Second. General map showing work so far completed or under contract.

Third. Section of St. Louis canal (24 feet 4 inches width and piling).

Fourth. Section of smaller drainage canal (8 feet width and no piling).

THOMAS DOANE.—A MEMOIR.

By Desmond FitzGerald, C. Frank Allen and Chas. A. Pearson, Committee of the Boston Society of Civil Engineers.

[Read September 20, 1899.*]

Thomas Doane was born September 20, 1821, at Orleans, Mass., and died October 22, 1897, at West Townsend, Vt., during a visit to that place from his home, in Charlestown. He could readily trace his ancestry to the early settlers in Massachusetts, he being a direct descendant, in the seventh generation, from John Doane, who came to Plymouth probably about the year 1630, and who seems to have been of much prominence in his time The earliest authentic records of Plymouth Colony in 1633 show John Doane to have been a member of the council to the Governor of Plymouth Colony, and, what was perhaps a greater distinction, that he was elected deacon during that year. Deacon John Doane was one of the seven heads of families who sailed from Plymouth in 1644 and first settled Eastham (then Nauset), which was incorporated in 1646, and from which Orleans was set off in 1797. It appears that he ranked among the seven as second in dignity only to Governor Thomas Prince. He represented his town as selectman, and also as deputy to the general court. He died in 1686, at the advanced age of ninety-six years.

John Doane, the father of the subject of this memoir, was also a man of note, having served as county commissioner, representative to the general court, State Senator, a member of the Governor's Council and a delegate to the convention of 1820 to revise the constitution of Massachusetts. "Squire" Doane, as he was known, was a lawyer of the type to which the word counselor best applies, and had the reputation for discouraging, rather than provoking, litigation. He was one of the company which built the Orleans Academy, and was among the first, if not the earliest, in this country to engage in arboriculture, planting many acres in pine and oak trees.

The mother of our Thomas Doane was Polly Eldridge, and there were eight children, only one of whom, Charles, is now living. Thomas, the eldest, attended the Orleans Academy, and later the English Academy at Andover, Mass. His school education ended when he was about twenty-one years old, and he then entered as "student" the office of Samuel M. Felton, a noted civil engineer,

*Manuscript received November 14, 1899.—Secretary, Ass'n of Eng. Socs.

then practicing in Charlestown. Mr. Felton was a member of this Society until his death, and Mr. Doane served there what might be called his apprenticeship of three years. Immediately after this he was placed in charge, under Mr. Felton, of the Windsor White River division of the Vermont Central Railroad, and later was for two years resident engineer of the Cheshire Railroad, with headquarters at Walpole, N. H.

In December, 1849, Mr. Doane returned to Charlestown and, in company with his brother, John Doane, Jr., opened an office under the firm name of T. & J. Doane, Jr., for the general p actice of civil engineering and surveying, an office which was maintained until his death. During his extended absences from Charlestown the conduct of the business was in the hands of trusted assistants. The firm also maintained for many years, ending in 1870, a Boston office; first at 4 Cornhill Court, and later in Barrister's Hall, Court Square, a building which was then occupied by several others of the best known and successful engineers of a generation or more ago, a number of whom are still living.

During the early fifties Simeon Borden, who made the trigonometrical survey of Massachusetts, spent much of his time in the Doane office in Cornhill Court. In the Charlestown office were retained many old plans and notebooks of value, including those formerly belonging to Mr. Felton which had come into the possession of Mr. Doane.

In October of 1863, after the commonwealth had undertaken the work of continuing the construction of the Hoosac tunnel, Mr. Doane was appointed chief engineer under a State commission consisting of John W. Brooks, Samuel M. Felton and Alexander Holmes. Upon assuming control he revised the line of tunnel location, "boldly locating on a tangent throughout." He did away with the slight angle at the center adopted by the engineers previously in charge, and on his location the tunnel was finally constructed. Under his direction were carried on the very careful preliminary operations for determining the final line over the mountains; work done with a degree of precision which rendered possible the meeting of the lines with an error in alignment of nine-sixteenths of an inch in one case and five-sixteenths of an inch in the other, although the points were, in the first case, 2056 feet from the shaft and 10,138 feet from the portal, and in the other 1563 feet and 11,274 feet respectively. It was Mr. Doane who ordered the large Temple transits which were an important factor in securing the exact alignment. His measurements for distance and level were also made over the mountain with painstaking accuracy, and with almost equally satisfactory results.

It was, however, in the construction work of the tunnel, or, more definitely, in introducing and developing better methods of rock drilling and blasting, that Mr. Doane's most valuable services were rendered and his greatest distinction as an engineer achieved. Experimental studies were made, and critical attention was given by him touching the use of nitro-glycerine for blasting, of compressed air for rock drills, to the form and details of rock drills and carriages and to the electrical firing of charges. In 1866 he introduced into this country the frictional ebonite battery for electrical firing, by which he was able to fire simultaneously thirty-one charges, as compared with five charges, which he found the limit with Shaffner's electro-magnetic system.

Of his work in connection with rock drilling and explosives, Drinker, in his great work on "Tunneling," says: "In fact, it is to the Hoosac tunnel that we owe the development of rock drilling machinery in America." "Experiments were made by the Massachusetts State Commission." "They were supported by Mr. J. W. Brooks, chairman of the commission, but they were chiefly carried on under the direction of Mr. Thomas Doane, then chief engineer of the tunnel.

"Air compressors were first applied for purposes of rock drilling at the Hoosac tunnel." "Mr. Thomas Doane had the experiments in charge." "To Mr. Doane is chiefly due the larger share of the credit for the persistent efforts made by the commission to develop practical rock-drilling machinery. He originally invented many points connected with such machinery, for some of which he holds patents; others were allowed to pass without patenting." "Among the first men in America to encourage the introduction of nitro-glycerine was Mr. Thomas Doane, who, when acting as chief engineer of the Hoosac tunnel in 1866, caused Shaffner to make a number of trials with the (then) new blasting agent. These trials were eminently successful, and ultimately led to the permanent adoption of nitro-glycerine in place of black powder in the tunnel.

"So many able and distinguished engineers and contractors have, during the progress of the Hoosac tunnel, contributed in a greater or less degree to its final success that it would be out of place in a record such as this purports to be for the author to attempt to give especial credit to any, where so much was done by all, in the work of the tunnel proper. But Mr. Doane's connection with the Hoosac tunnel in the early days of that great work is not a matter of especial, but of universal, interest to the engineering profession in America; for to his persistent energy, his far-seeing sagacity and his able management we in a large measure, and in

fact chiefly, owe the development and introduction into this country of the present advanced system of tunneling with machinery and high explosives. It was under his direction, as engineer of the commission, that the State experiments were made, and the long and disheartening fight carried through which terminated in favor of the new system; the system which has since given us the Burleigh, Ingersoll and Wood drills, and which also first showed Americans practically what the potent agency of nitro-glycerine first applied by Nobel in Europe in reality was."

In connection with the tunnel work he constructed the dam across the Deerfield River, 250 feet long and 20 feet high, a work of some importance at that time. It was built to furnish power for a machine shop and to operate the machine drills, and also to furnish ventilation for the tunnel. This work was in charge of Hiram F. Mills, as assistant engineer. Charles S. Storrow was consulting engineer. James B. Francis was also consulted, and gave his approval to the location and plan.

Mr. Doane resigned his position as chief engineer of the Hoosac tunnel in 1867, but was afterwards employed as an expert, with others, to determine the amount of lining necessary for the tunnel, and was given charge of doing this work under the title of consulting engineer. In 1875, at the opening of the tunnel, Mr. Doane ran the first engine, the "N. C. Munson," through it. Even after resigning his position as chief engineer he maintained his interest in the question of the use of compressed air and the perfecting of machinery for its production and use, in which he was an advanced thinker; and in 1873 published an article in which he advocated some of the methods which are coming into favor at the present time.

In 1869 Mr. Doane became the chief engineer of the Burlington and Missouri River Railroad in Nebraska, a part of the Chicago, Burlington and Quincy Railroad, extending west from Plattsmouth, at which point he established a steam ferryboat service as a necessary part of the system. As would be expected by any one familiar with Mr. Doane's views on the subject, special effort was made to secure as low grades as possible in order to secure economy in operation, and at the few points where higher grades seemed unavoidable arrangements were made to use auxiliary power. This railroad was built with a thoroughness unusual in that section of the country. Howe trusses on masonry abutments were used in crossing streams, in accordance with New England custom. In two cases on Salt River the rather unusual device of piers of screw piles was adopted. Hardwood ties of oak were used under the

rails, and careful attention was given to the drainage of the roadbed. In fact, the expense of the work, due to securing low grades and more permanent work than was there customary, led to unfavorable criticism. However, after the railroad had been in operation about a year Mr. John W. Brooks, president of the railroad, and himself a civil engineer, in a report to the directors said: "Your road was built by an engineer who did not know how to build a poor one. We have an opportunity to judge of the value of light gradients, for as our business increases, instead of multiplying trains, we have but to add cars to trains already scheduled." It is said that one train from the West arriving at Plattsmouth would have made three in its further journey across Iowa.

Upon completion of the railroad in 1873 Mr. Doane returned to the East. In addition to the work on the Hoosac tunnel, he was given charge of the relocation and construction of the Troy and Greenfield Railroad, on which there was a large amount of heavy work in the way of abutments, piers, culverts and retaining walls, as well as in excavation of earth and rock in large quantities. Much of it was mountain side-hill work, in which there was danger from washouts on one side and from landslides on the other.

In 1879 Mr. Doane again went West, having received the appointment of consulting and acting chief engineer of the Northern Pacific Railroad. He served in that capacity for one year, reorganizing the engineering force and giving his attention largely to locating what was known as the Pend d'Oreille division, crossing the Columbia Plains in Washington Territory. In Dakota, part of the Missouri division was located under his direction during that time. While with this railrcad he found that the movement of railroad materials would be greatly facilitated if a track could be carried across the Missouri River, and he therefore built during the winter a railroad across the ice which was of considerable value for this purpose.

In 1880 he made a railroad reconnoissance in West Virginia, and prepared a profile by the aid of an aneroid barometer only; the line being 150 to 200 miles in length, and the exploration being accomplished on horseback with a single guide in the brief period of about ten or twelve days. A year later the line was chartered as the Atlantic and Ohio Railroad, with Mr. Doane as chief engineer. Some work of location was done, but financial troubles soon put a stop to further work. As an example of Mr. Doane's standard of honor, it is related by Mr. C. W. Folsom, of this Society, that "about two months' pay was due the engineers, and Mr. Doane, with rare chivalry of character, assumed the liabilities of the com-

pany and paid us out of his own pocket. He had made himself in no way legally responsible, but, we having come out to that inhospitable wilderness on his invitation, he seemed to consider himself in honor bound to see us through. He was never remunerated for this outlay by any of the projectors."

For a number of years past Mr. Doane had often been consulted by many of the railroads centering in Boston on important matters connected with their plans, and had frequently been called upon to give expert testimony in the courts. He had also given similar service to the Railroad Commission; one of the most important reports in this connection being the report on the proposed Northern Union Station, which was, however, finally built upon a plan different from that advocated by him.

He reported upon the condition of many of the street railways of the State, and was employed as consulting engineer of the West End Street Railway when Henry M. Whitney was president and the question of motive power was under consideration. In the winter of 1887-88, in company with other officials of the railway, he visited a number of Western cities for the purpose of examining cable systems. He also went to Nova Scotia to examine and report on a route for a railroad to transport coal from the mines of the Dominion Coal Company to the coast.

A large part of the engineering for the city of Charlestown was done by Mr. Doane previous to that city becoming a part of Boston in 1874. In fact, it is stated that there is hardly a lot in Charlestown which he had not at some time surveyed. Mr. Doane was doubtless the first surveyor in this section who referred his surveys to a meridian passed through any definite permanent point. His survey of Charlestown, made many years ago, showed all the base line points, as well as many others, by their co-ordinates with reference to the State House.

For more than twenty years, and until the time of his death, Mr. Doane was an active member of this Society. He was elected President shortly after its reorganization in 1874, and was nine times re-elected to serve in that honorable position. He always took a great interest in its affairs, and was very regular in his attendance at its meetings. He served on important committees, notably those on finance and on permanent headquarters. His interest in the Society was maintained to the last. He became a member of the American Society of Civil Engineers in 1882.

From 1869 to 1873, while a resident of Nebraska, Mr. Doane was instrumental in founding "Doane College," situated at Crete, on the "Big Blue" River, twenty miles west of Lincoln, and one of

the leading institutions of education in the State. Offers by the railroad company of six hundred acres of choice land adjoining the town site, and of fifty lots in the town of Crete, by the Eastern Land Association, of which Mr. Doane was a member, were made on condition that other valuable property be secured. Through Mr. Doane's influence and his own liberal financial contributions these conditions were fulfilled, and in appreciation of his efforts his name was given to the college. It contains four substantial brick buildings, a spacious campus, well-equipped laboratories and dormitories for both sexes. It maintains classical and scientific collegiate courses, a military department and a conservatory of music. Mr. Doane rarely failed to attend the commencement exercises, making yearly a trip to Nebraska for this purpose. He was one of the trustees at the time of his death. He had prospered financially, and by his will the bulk of his estate will eventually go to Doane College as an endowment.

Mr. Doane was twice married: on November 5, 1850, to Miss Sophia D. Clarke, who died December 1, 1868, and again November 19, 1870, to Miss Louisa A. Barber, who now survives him, as do also four children by his first marriage.

Mr. Doane possessed something of the religious spirit, which was his rightful inheritance through a long line of ancestors, several of whom were deacons; and he early associated with the church, being for many years a member and for fourteen years himself a deacon of the Winthrop Congregational Church of Charlestown. He was also the first president of the Charlestown branch of the Young Men's Christian Association, and was a member of the Congregational Club of Boston. His religion was of the sort that associates good deeds with the devotional spirit, for he was enthusiastic and generous in his support of charitable and philanthropic work. He was a director of the Associated Charities of Boston, and president of its Charlestown branch. He was a vice-president of the Hunt Asylum for Destitute Children, and a member of the Bunker Hill Boys' Club.

His interest in good citizenship was manifested by his membership in the Municipal League of Boston, and his frequent attendance at their meetings. He was a member of the New England Historic Genealogical Society and of the American College and Educational Society, and was for more than thirty years a justice of the peace.

Success in his profession was the legitimate result of his character and personal qualities. He was possessed of a high sense of honor, both personally and professionally, and was firm, even tena-

cious, in his convictions and of unflinching integrity. His sound judgment, breadth of treatment, energy and love of accuracy, led to the success of the enterprises entrusted to his charge. No difficulty daunted his courage. Work done by him must be good work or none. He would resign rather than imperil life by imperfect construction. He was not content to build for the present only, but constructed for the future as well. From a long line of ancestry he inherited the responsibility of maintaining the family standard, which was high both in ability and in character; and, in view of his professional services in engineering and their great value to civilization in advancing the general welfare of mankind, of his splendid contribution to the cause of education, his general philanthropic work, as well as of his personal character, it can be truly said that the talent received from his Master he returned increased many fold.

CLARENCE ALLAN CARPENTER.—A MEMOIR.

By E. A. Handy, August Mordecai and F. C. Osborn, Committee of the Civil Engineers' Club of Cleveland.

Never before in the history of this Club have we been called upon to mourn so sudden and so sad a death as was that of our esteemed fellow-member, Clarence Allan Carpenter, who, on the 7th of November, was struck down, near Geneva, Ohio, in the active performance of his duties as engineer of the Lake Shore division of the Lake Shore and Michigan Southern Railway. He had parted from his family but a few short hours before in good health and spirits, only to be brought back to them fatally injured. For two days he lingered between life and death, and for some time it was earnestly hoped that his life might be saved. But he had been too terribly hurt to survive, and on the 9th of November he died.

Mr. Carpenter was born at Dedham, Mass., in 1846. He was the only son of John Allan Carpenter, a well-known contractor, whose works in the construction of the Fitchburg Railroad, the Old Colony Railroad, the Lawrence Dam and many other important enterprises will long survive.

He was educated as a civil engineer at Union College, at Schenectady, N. Y., and began his professional career on the Adirondack Railroad, in Northern New York State. He consecutively followed his profession in positions of responsibility on the Missouri, Kansas and Texas Railroad, the New York and Canada line of the Delaware and Hudson Canal Company and the Little Rock and Fort Smith, the Union Pacific and the Chicago, Milwaukee and St. Paul Railroads. With the last-named road he spent eleven years, attaining the position of first assistant engineer. Later he was engaged in surveys for the Atchison, Topeka and Santa Fe system in California, soon returning, however, to take the position of division engineer on the Northern Pacific Railroad at Helena, Mont. In the fall of 1891 he accepted the post of division engineer of the Lake Shore and Michigan Southern Railroad, which he held till his untimely death.

Mr. Carpenter's reputation for care and accuracy was wide-spread, and his rare capacity for detail rendered him peculiarly fitted for the positions he held. Nothing connected with his department was of too little importance to claim his careful personal attention and skillful execution, while the effect of his broad and com-

prehensive grasp of the greater problems always won the confidence of his employers.

He had been a member of our Club since January, 1894, and was frequently among us at our meetings, always interested in the proceedings and in the welfare of the Club.

Although quiet, unassuming, even retiring, in disposition, he was, nevertheless, universally beloved among his many friends and acquaintances. There was not a man on this division of the Lake Shore Railway, from the highest officials to the section hands, who did not know him and respect him for his sterling character and generous heart.

It is particularly sad that so able a member, and one so universally beloved and respected, should be thus suddenly cut off in the midst of his career among us. His memory will be always with us, and it is meet that the following resolutions be adopted in his memory:

WHEREAS, An all-wise Providence has seen fit to remove from our midst another of our esteemed brethren; and

WHEREAS, It is fitting that the memory of his life and character be preserved to us; be it therefore

Resolved, That in the sad and untimely death of Mr. Clarence Allan Carpenter, the Civil Engineers' Club of Cleveland has lost one of its ablest and most respected members; and be it further

Resolved, That the sincere sympathy of the Club be extended to his family in their bereavement; and be it further

Resolved, That the Secretary be instructed to spread these resolutions and the accompanying memoir upon the records of the Club and to transmit a copy of these resolutions to the family of our deceased brother.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1885. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis,

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING, HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and the transactions of the participating Societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative

from each Society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each Society shall decide, and shall hold office until their successors are chosen.

Sec. 2. The officers of the Board shall be a Chairman and Secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

Section 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

Sec. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the Chairman for countersignature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

Section 1. Each Society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

Sec. 2. Each Society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any Society may be used as it shall see fit. Payments by each Society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions, as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any Society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any Society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating Societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three Societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several Societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following Societies have since certified their acceptance of the articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.
Detroit Engineering Society, January, 1897.
Engineers' Society of Western New York, January, 1898.
Louisiana Engineering Society, September 15, 1898.
Engineers' Club of Cincinnati, January, 1899.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.
The Western Society of Engineers withdrew in December, 1895.
The Engineers' Club of Kansas City disbanded at the close of 1896.
The Denver Society of Civil Engineers and the Association of Engineers of Virginia disbanded in 1898.

Annual Report of the Chairman of the Board of Managers.

DECEMBER 30, 1899.

To the Members of the Board of Managers of the Association of Engineering Societies.

GENTLEMEN:—I have the honor to present to the Association, through you, the annual report of the Chairman for the year 1899.

The principal business of the board is the publication of the JOURNAL, which has appeared with regularity through the year, the quality of papers presented and the mechanical execution being maintained at the standard of excellence of previous years. Aside from the JOURNAL, the routine of whose publication is practically all attended to by your efficient Secretary, very little business has been transacted by the board. Other than the admission of the Engineers' Club of Cincinnati and the election of officers for the ensuing term of two years, practically nothing has come before the board for general action. A few details of routine have been adopted, such as printed ballot blanks and the appointment of an Auditing Committee to examine the accounts of the Association. Heretofore there seems to have been no regular system of examining the accounts aside from that done by the Secretary and the approval of bills by the Chairman. I have taken the liberty of appointing an Auditing Committee, whose report is expected in this issue. It is recommended that such an examination be made at least biennially hereafter.

I take pleasure in transmitting the report of the Secretary, whose efficient work has been before you month by month in the JOURNAL. Allow me to emphasize the remarks of the Secretary regarding the falling off in the proportion of papers per member submitted for the JOURNAL, there being only 35 papers in 1899, as against 45 in 1898 and in 1897. This may be accounted for by the revival of business, which has stimulated engineering enterprises, so that doubtless fewer engineers have sufficient time to prepare set papers for publication. While thankful for prosperous times, let us not neglect to keep up the quality and quantity of matter submitted for the JOURNAL. With the large membership in the Association, now reaching 1475, it should be possible to maintain the JOURNAL at so high value that no engineer could afford to be without it. Such would make material increase in the number of subscribers, and would make it still more of an object for outstanding societies to join the Association that their members might secure the JOURNAL at the low rate prevailing for members of the Association.

The financial condition of the Association is a matter for congratulation, and the statistical report, with remarks of the Secretary, are commended for careful perusal.

The list of members of the Societies, the publication of which was begun last year, and is made more complete this year, is believed to be a desirable feature.

To increase to some extent the accessibility of the JOURNAL to members and others who may not have their own files at hand, the Secretary has been compiling a list of the public libraries which have complete or partial files of the JOURNAL. Probably most of the affiliated Societies are having their free copies distributed to the public libraries in their vicinities. It is believed that the Association might well afford to send free copies of the JOURNAL to a number of the more prominent libraries in cities where there is no society of engineers connected with the Association. Such action is commended.

The attention of the publishers of the *Engineering Magazine* has been called to the desirability of collating the "Index of Engineering Literature" appearing in that magazine, and of publishing an annual or biennial volume somewhat as was formerly done in connection with the JOURNAL. It seems to have been the understanding that such was to be done when the index in connection with the JOURNAL was discontinued in 1895. I am informed that the preparation of Volume III of such an index is well under way by the *Engineering Magazine*, bringing the index down to 1899. It is to be hoped that this invaluable volume will soon be ready.

In closing this, my retiring report, I wish again to thank the members of the board for honoring the representative of the smallest Club in the Association by electing him your Chairman, and to assure you of our hearty co-operation in the future work of the Association.

Respectfully submitted,

GEO. D. SHEPARDSON, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, December 30, 1899.

Prof. George D. Shepardson, Chairman,

University of Minnesota, Minneapolis, Minn.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1899, and of the condition of the Association at the present time.

These data are concisely stated in the following statistical appendices:

A. Statement of receipts and expenditures during 1899.

B. Estimate of assets and liabilities at the close of 1899.

C. Detailed statement of cost of JOURNAL during 1899, by months.

D. Comparison of mailing lists of the JOURNAL at the close of 1898 and of 1899, respectively.

E. Statement of material in JOURNAL during 1899, by pages.

F. Comparison of conditions, 1894 to 1899, inclusive.

F (a). Diagram of aggregate membership and of net assets, 1894 to 1899, inclusive.

F (b). Diagram of cost of JOURNAL per member, and of annual assessment, 1894 to 1899, inclusive.

G. Comparison of conditions between the Association of Engineering Societies and the three large outstanding engineering Societies,—viz, the Western Society of Engineers (Chicago), the Engineers' Society of Western Pennsylvania (Pittsburg) and the Engineers' Club of Philadelphia (Philadelphia).

G (a). Graphic representation of portions of Appendix G.

A study of these appendices, and particularly of Appendix F, and of the diagrams F (a) and F (b), shows that the prosperous condition of the Association, which has characterized the last few years, continues in full force; while Appendices G and G (a) show the efficiency of the Association as compared with that of individual Societies.

Not only was the unprecedentedly low rate of assessment ($2.00 per annum per member) of 1898 continued during 1899, but a rebate of $1.00 per member (amounting to about $1400 and reducing the net assessment to $1.00) was made for the purpose of reducing the large surplus ($2936.71) in hand at the close of 1898; but, notwithstanding this, the close of 1899 shows the large surplus of $2442.70.

The admission of the Engineers' Club of Cincinnati, with a membership of 97 names, which was pending at the close of 1898, was consummated in January, 1899; and the Virginia and Denver Societies, with 14 and 25 names respectively, which had practically gone out of existence during 1898, were dropped from the list of Societies during 1899. The list therefore shows a net loss of one, in the number of Societies, as compared with the close of 1898; but this loss is more than

compensated by the much larger membership of the Cincinnati Society and by substantial gains (as against trifling losses) in the memberships of the other Societies. The Association now comprises eleven Societies, with an aggregate membership of 1475. (See Appendix D, and columns 1 and 2 of Appendix F, also F (a).)

The locations and memberships of these Societies are indicated on the map, page 91, where each circle shown for a Society represents 100 members or fraction of 100.

Each Society, added to the Association, increases (1st) the amount of material furnished to each member, (2d) the circulation given to it, and (3d) the difficulty of explaining why any engineering Society in good standing should fail to join the Association.

The subscription and exchange lists, which have been well maintained during the last six years, show slight gains. (Columns 3 and 4, Appendix F.)

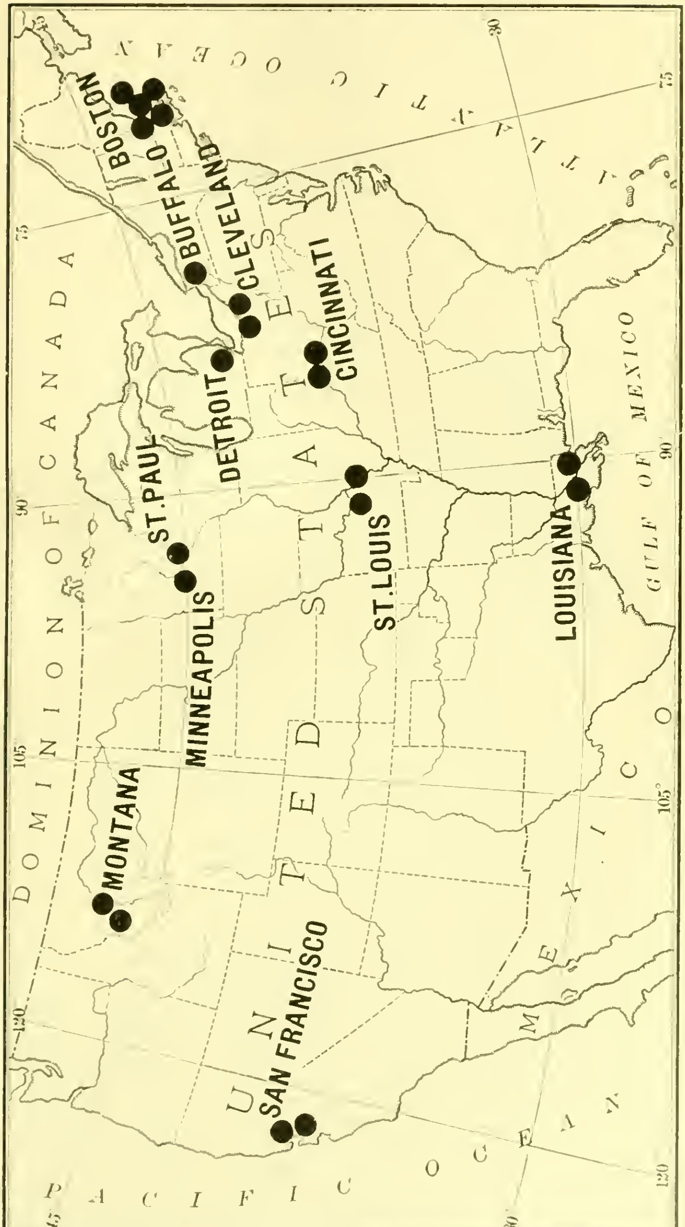
During 1899 commendable activity has been manifested by the Cleveland Society in obtaining advertisements for the JOURNAL. Under the present ruling of the Board, by which the Association allows to any Society 90 per cent. of the gross receipts from advertisements obtained by it, the Societies are enabled to lighten materially the already easy burden borne by their members on account of the Association; and yet the net receipts from advertisements show a considerable falling off. (Column 5, Appendix F.)

Columns 7 and 8 of Appendix F show a decided falling off in the amount of material presented for publication in the JOURNAL, the total number of pages of papers having fallen from 738, in 1898, to 544, in 1899, and the number of pages per 1000 members from 539 to 369. The last named is the lowest reached during the last six years, and argues a low average literary activity among the members of the Societies.

This is much to be regretted; for, with the membership which the Association now enjoys, its JOURNAL should be such that no engineer could afford to be without it, and the subscription list alone should cover the entire cost of publication, relieving the Societies of the burden of assessments. Fortunately, all indications point to a larger volume in 1000.

The gross cost of the JOURNAL, per page (column 10), in 1899 shows a slight increase over 1898; but the gross cost per member ($2.19) shows a marked reduction, notwithstanding the very low figures ($2.51 and $2.53 respectively) for 1897 and 1898. As a part

LOCATIONS AND MEMBERSHIPS OF THE SOCIETIES COMPOSING THE ASSOCIATION. EACH DOT REPRESENTS 100 MEMBERS OR FRACTION OF 100. AGGREGATE MEMBERSHIP 1475.



of this reduction may properly be attributed to the reduction in the total number of pages in the JOURNAL (column 6), column 12 has been prepared, giving the gross cost per member per 1000 pages, and this shows practically no change as between 1898 and 1899, the figures for which are the lowest during the six years embraced in the table. See also diagram, Appendix F (b).

The annual assessment for 1899 ($2 per member) was already less than the gross cost of the JOURNAL for that year ($2.19 per member), and the gross cost during 1900 will be materially increased by an advance in printers' prices.

The uniform and rapid increase of the net assets of the Association, notwithstanding a steady reduction of assesments and the maintenance of the typographical character of the work, is shown in column 17 of Appendix F, and graphically in Appendix F (a), where it will be seen that, but for the rebate of $1.00 per member in 1899, reducing the net assessment to $1.00 and amounting to about $1400, the rate of increase of the surplus, which has remained nearly constant during the last six years, would have been maintained, and the surplus would have reached nearly $4000.

It is felt, however, that the object of the Association is not to accumulate a large and nearly idle surplus, but to give to its members the best possible service at the least possible cost, and that there should be retained, in the treasury, only such a balance as will afford a sufficient working capital with due regard to an increase of expenses such as now confronts us. Hence the lowering of the assessment rate in 1896, 1897 and 1898, and the special rebate (equal to half the assessment) in 1899.

The true index to the efficiency of the Association, as a means for the proper and economical publication of the papers of engineering societies, is found in Appendix G, which gives, in addition to the membership and the number of pages in the JOURNAL, the gross and the net cost per member, at or about the present time, for the Association and for the three large outstanding Societies,—viz, those with headquarters at Chicago, Pittsburg and Philadelphia respectively.

As the total cost per member is misleading unless the volume of matter furnished to each member is taken into account, the cost per member *per 1000 pages* is also given. The latter comparison, and that of memberships and pages in JOURNAL, is shown graphically in Appendix G (a).

The reports of the Chicago and Pittsburg Societies for 1899 not having reached me, I have been obliged to content myself with their figures for 1898.

In the absence of detailed figures giving the items regarded as making up the cost of the JOURNAL in the cases of the

outstanding Societies, some uncertainty attends the comparison shown in Appendices G and G (a). From a study of their reports, however, I gather that postage on the JOURNAL and salaries connected with the editing are not included in the figures given for the cost. I have, therefore, for the purpose of the present comparison, deducted those items from the cost of our JOURNAL as given in Appendix C.

The cost of publication is given, in each case, in three forms,—viz, (1) "Gross," giving the total amount expended, without offset on account of earnings by the JOURNAL; (2) "Gross, less sales," showing the effect of receipts from subscriptions for, and sales of, the JOURNAL, and (3) "Net," showing the further effect of receipts from advertisements in the JOURNAL.

What any of our Societies can do by securing advertisements for the JOURNAL OF THE ASSOCIATION is strikingly illustrated by the case of our Cleveland Society during 1899 and by that of the Western Society of Engineers during 1898.

In spite of the very high gross cost of $6.57 per member per 1000 pages in the case of the Chicago Society (due, no doubt, to great lavishness in the matter of illustrations, as well as to a relatively small membership), the net cost was reduced to only 55 cents per member per 1000 pages by the activity of the Society in procuring, for its *Journal*, a large number of paying advertisements; while our Cleveland Society, during 1899, by the same means, relieved itself *entirely* of charges on account of the Association JOURNAL, the discounts allowed to it by the Association balancing, within less than a dollar, the total net charge of $1.00 per member, made by the Association against the Society during the same year.

A comparison of the gross cost per member per 1000 pages between the four Societies, shows strikingly the value of co-operation in the publication of engineering papers. Apart from the manifest advantages of very much wider circulation, the actual cost of publication of our JOURNAL is seen to be roughly only from one-third to one-fourth of that in either of the three outstanding Societies.

Even in the case of the Pittsburg Society the cost is nearly three times ours, notwithstanding that in the Pittsburg Society, "in order to keep the cost of publication of papers within the limits of the resources of the society, the Board desires to impress on all authors the necessity of restricting their illustrations to a single page and to a limit of three pages." In 1898 the expenditure of the Pittsburg Society for illustrations was only $90.03, as against $729.38 in our case.

Unfortunately, the quality of engineering papers does not readily lend itself to either tabular or graphic representation; but if it be borne in mind that the aggregate membership of our eleven Societies is more than three times as great as that of the largest of these three large Societies (the Engineers' Club of Philadelphia), and that our membership is scattered over the United States from Boston to San Francisco, to Montana and to New Orleans, embracing very wide differences of practice arising from diversity of natural and economic conditions, it will be seen that the professional value and the literary merit of our papers can hardly be expected to suffer by comparison.

In the JOURNAL for January, 1899, there appeared a list of the members of all the Societies composing the Association. The suggestion for the publication of such a list came so shortly before the issue of the JOURNAL that it was impossible to ascertain the positions or occupations of all the members in season for insertion in the list, or to distinguish between the several classes of members.

In the list published in the present number these defects have been remedied, and the list is presented in what it is hoped will prove a more satisfactory typographical arrangement.

Respectfully submitted,
JOHN C. TRAUTWINE, JR., *Secretary*.

APPENDIX A.

STATEMENT OF RECEIPTS AND EXPENDITURES DURING 1899.

CASH, 1899.

Dr.

To Balance, January 1, 1899		$2,102 87
" Assessments, at $2.00 per member:		
Boston Society of Civil Engineers	$972 50	
Civil Engineers' Club of Cleveland	451 50	
Engineers' Club of St. Louis	395 50	

Civil Engineers' Society of St. Paul	$94 50		
Engineers' Club of Minneapolis	37 50		
Montana Society of Engineers	550 50		
Association of Engineers of Virginia	3 50		
Detroit Engineering Society	137 50		
Engineers' Society of Western New York	94 00		
Louisiana Engineering Society	111 00		
Engineers' Club of Cincinnati	202 00		
Technical Society of the Pacific Coast	341 00		
		$3.391 00	
To Initiation fee:			
Engineers' Club of Cincinnati		48 50	
" Subscriptions		431 24	
" Sales of JOURNALS		133 56	
" " " Descriptive Index		105 40	
" Advertisements		499 88	
" Sales of reprints		149 75	
" " " periodicals		28 00	
" Interest on deposits		62 62	
" Electros		11 25	
			$6,970 07

Cr.

By Rebates to Societies, at $1.00 per member:			
Boston Society of Civil Engineers	$486 25		
Civil Engineers' Club of Cleveland	225 75		
Engineers' Club of St. Louis	197 75		
Civil Engineers' Society of St. Paul	47 25		
Engineers' Club of Minneapolis	18 75		
Montana Society of Engineers	275 25		

Detroit Engineering Society	$68 75		
Engineers' Society of Western New York	47 00		
Louisiana Engineering Society	55 50		
Engineers' Club of Cincinnati	101 00		
Technical Society of the Pacific Coast	170 50		
		$1,693 75	
By Patterson & White (Printers)		2,150 00	
" Illustrations		354 31	
" Secretary's salary		600 00	
" Car fares		1 52	
" Mimeographing, etc.		3 85	
" Discounts on subscriptions		21 10	
" " " sales		1 25	
" " " advertisements		109 00	
" Messenger service		2 25	
" Stationery		4 15	
" Telegrams		2 26	
" Postage stamps		28 22	
" Express charges		2 83	
" Back numbers bought		2 50	
" Binding JOURNALS		3 00	
" Electrotypes		22 24	
" Provident Life and Trust Company, to cover deposits returned to Secretary for correction		12 60	
" Binding indexes		13 90	
" John C. Trautwine, Jr., to refund amount paid by him for advertisements covered by exchange		75 00	
			$5,103 73
" Cash balance, December 31, 1899			$1,866 34

7

APPENDIX B.

Estimate of Assets and Liabilities at the Close of 1899.

AVAILABLE ASSETS.

Cash balance, December 31, 1899		$1,866 34		
Less subscriptions for 1900, paid during 1899		61 00		
			$1,805 34	
Amounts receivable from Societies (for assessments, etc.):				
Detroit Engineering Society		$24 50		
Subscriptions due:				
For 1899	$324 00			
" 1898	156 00			
" 1897 and earlier	174 00			
		654 00		
For reprints		95 10		
" advertisements		302 66		
" sales of Journals		8 10		
" " " Index		5 00		
" cuts and electros sold		25 31		
" insets		12 00		
			1,126 67	
			$2,932 01	

LIABILITIES.

Patterson & White (Printers):				
Balance, December 30	$237 86			
For December Journal	172 94			
" reprints	6 91			
" blocking cuts	4 90			
		$422 61		
Engineers' Club of St. Louis		9 50		
Civil Engineers' Club of Cleveland, amount still due from advertisement		16 20		
L. L. Poates, illustrations		41 00		
			489 31	
Net Assets			$2,442 70	

APPENDIX C.

Detailed Statement of Cost of Journal during 1899, by Months.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	Printer. Sum of 1, 2, 3 and 4	Illustrations.*	Cost of Manufact'e Sum of 1, 2, 6.	Wrappers.	Secy's Salary.	Sundries.†	Total. Sum of 5, 6, 8, 9, 10.	No. of Pages.‡	Cost per Page. ‡
January	$117 07	$119 75	$9 08	$11 09	$256 99	$36 46	$273 28	$4 75	$50 00	$10 45	$358 65	112	$3 20
February	40 35	57 25	5 53	5 57	108 70	....	97 60	4 75	50 00	49 76	213 21	58	3 68
March	56 08	72 50	5 08	9 42	143 08	72 43	201 01	4 75	50 00	20 78	291 04	78	3 73
April	99 95	125 35	6 32	11 63	243 25	68 59	293 89	4 75	50 00	8 26	374 85	130	2 88
May	105 16	94 50	4 90	10 37	214 93	55 60	255 26	4 75	50 00	9 76	335 04	108	3 10
June	34 25	51 00	4 35	6 04	95 64	6 00	91 25	4 75	50 00	4 81	161 20	54	2 99
July	60 00	72 50	6 70	9 26	148 46	70 42	202 92	4 75	50 00	2 65	276 28	78	3 54
August	65 05	73 00	4 49	9 32	151 86	92 55	230 60	4 75	50 00	9 72	308 88	84	3 68
September	36 68	57 25	5 55	5 86	105 34	20 72	114 65	4 75	50 00	1 65	182 46	58	3 15
October	50 44	60 00	5 00	9 55	124 99	131 72	242 16	4 75	50 00	8 73	320 19	68	4 71
November	32 63	53 25	4 82	5 87	96 57	6 75	92 63	4 75	50 00	8 82	166 89	56	2 98
December	66 29	88 25	6 20	7 45	168 19	....	154 54	4 75	50 00	21 81	244 75	74	3 31
Totals and averages	$763 95	$924 60	$68 02	$101 43	$1,858 00	$561 24	$2,249 79	$57 00	$600 00	$157 20	$3,233 44	958	$3 38

*The figures in column 6 (Illustrations) include preparation of cuts and lithographic stones, and paper and presswork on insets.

†The figures in column 10 (Sundries) include all expenditures of the Association (such as stationery, postage, circulars, etc.) chargeable to the Journal and not embraced in any other column. They do not include the cost of preparing reprints of papers.

‡The figures in columns 12 (No. of Pages) and 13 (Cost per Page) include 4 cover pages in each number, and 16 pages in indexes to Vols. XXII and XXIII.

APPENDIX D.

Comparison of the Mailing Lists of the Journal, at the Close of 1898 and of 1899, Respectively.

	1898.	1899.	Increase.	Decrease.
Boston Society of Civil Engineers	485	495	10	..
Engineers' Club of Cleveland	177	185	8	..
Engineers' Club of St. Louis	191	206	15	..
Civil Engineers' Society of St. Paul	33	29	..	4
Engineers' Club of Minneapolis	21	19	..	2
Montana Society of Engineers	107	107	..	..
Technical Society of the Pacific Coast	126	146	20	..
Denver Society of Civil Engineers	25	..	..	25
Association of Engineers of Virginia	14	..	..	14
Detroit Engineering Society	91	97	6	..
Engineers' Society of Western New York	43	43	..	..
Louisiana Engineering Society	57	53	..	4
Engineers' Club of Cincinnati	..	95	95	..
	1370	1475	154	49
Net Increase, 105				
Extra copies to Societies	38	46	8	..
Advertisers	19	18	..	1
Exchanges	114	115	1	..
Subscribers	246	249	3	..
Complimentary copies	10	1	..	9

Besides this, many copies have been sold and specimen copies sent out; and authors of papers have each received five copies of the Journals containing them. Two thousand copies of the January number were printed, 2250 of April and 2100 of each of the other months.

APPENDIX E.

STATEMENT OF MATERIAL IN JOURNAL DURING 1899, BY PAGES.

	Papers.	Proceedings.	Chairman's Report.	Advertisements.	Indexes to Vols.	List of Members.	Totals.	Cuts.	Plates and full page cuts.
January	32	24	12	16	..	24	108	11	2
February	26	12	..	16	..	..	54	..	..
March	42	16	..	16	..	..	74	15	2
April	92	18	..	16	..	..	126	21	3
May	70	18	..	16	..	..	104	4	4
June	22	4	..	16	8	..	50	6	..
July	56	2	..	16	..	..	74	9	3
August	62	2	..	16	..	..	80	2	3
September	32	6	..	16	..	..	54	5	1
October	44	4	..	16	..	..	64	9	11
November	32	4	..	16	..	..	52	32	..
December	34	12	..	16	8	..	70	10	1
Totals	544	122	12	192	16	24	910	124	30
Covers							48		
Total							958		

APPENDIX F.

Comparison of Conditions, 1894 to 1899, Inclusive.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
							Pages of Papers.		Cost of Journal *					Illustrations.			
Year.	Number of Societies in Association, Dec. 31.	Aggregate Membership of Societies, Dec. 31.	Subscribers, Dec. 31.	Exchanges, Dec. 31.	Net Receipts from Advertisements.	Total Number of Pages in Journal.	Total.	Per 1000 Members.	Total.	Per Page.	Per Member.	Per Member per 1000 pages.	Annual Assessment per Member.	Small Cuts.	Plates and Full-Page Cuts.	Cost.	Net Assets, Dec. 31.
1894	8	1174	176	110	$671 00	1290	653	556	$5774 59	$4 48	$4 92	$3 81	$3 00	86	54	$651 60	—$758 91‡
1895	11	1477	215	122	599 09	1482	792	536	5911 48	3 99	4 00	2 70	3 66	116	66	859 60	223 93
1896	9	1106	241	108	763 25	856	490	443	3928 42	4 59	3 55	4 15	3 00	62	56	771 39	1244 94
1897	10	1252	233	102	410 25	1016	638	510	3140 43	3 09	2 51	2 47	2 50	57	45	503 85	2562 04
1898	12	1370	246	114	465 58	1110	738	539	3462 08	3 12	2 53	2 28	2 00	166	42	729 38	2936 71
1899	11	1475	249	115	390 88	958	544	369	3233 44	3 38	2 19	2 29	2 00†	124	30	561 24	2442 70†

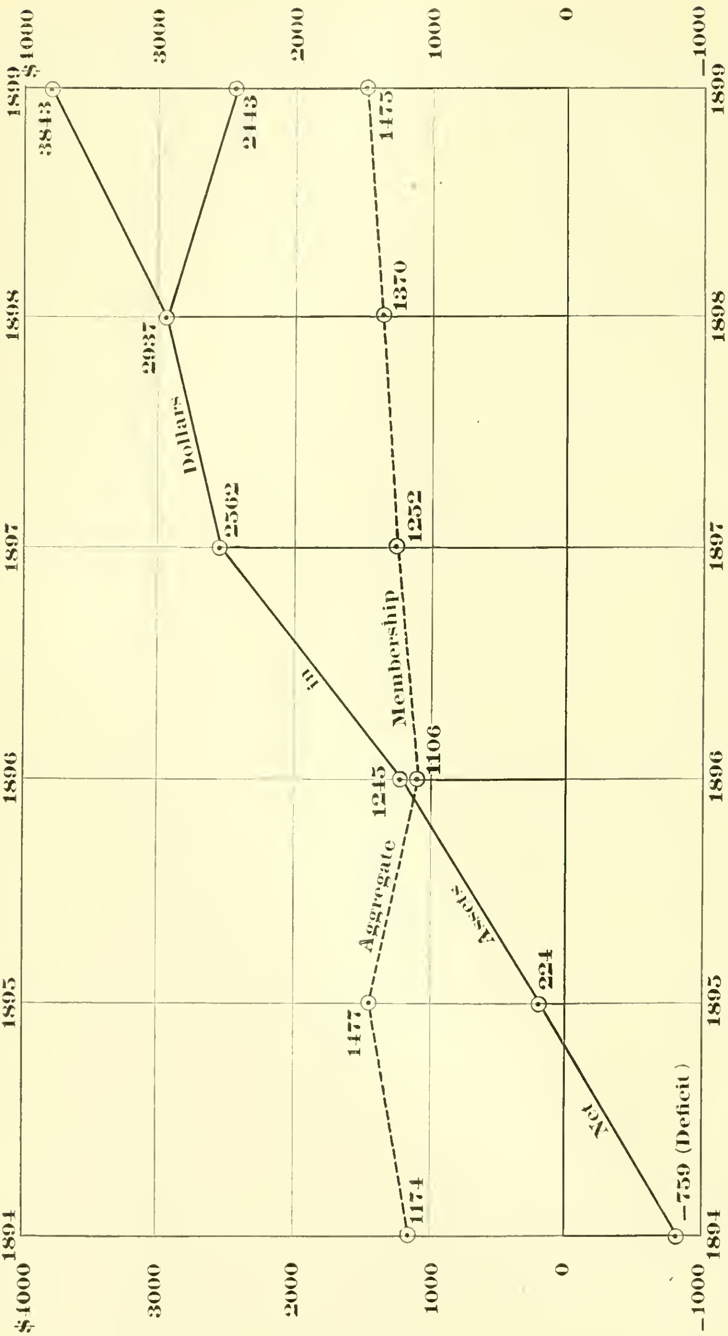
*The publication of the Descriptive Index of Current Technical Literature was discontinued at the end of 1895.

†During 1899, with an assessment of $2.00 per member, the Association made a rebate of $1.00 per member for the purpose of reducing surplus, making the actual charge only $1.00 per member, and reducing the assessment by about $1400.

‡Deficit at close of 1894. Since then, each year has shown a surplus.

APPENDIX F (a).

Diagram of Aggregate Membership and of Net Assets, 1894 to 1899, Inclusive.



APPENDIX F (b).

Diagram of Cost of Journal per Member, and of Annual Assessment, 1894 to 1899, Inclusive.

APPENDIX G.

COMPARISON OF CONDITIONS

BETWEEN THE

ASSOCIATION OF ENGINEERING SOCIETIES

AND THE

THREE LARGE OUTSTANDING ENGINEERING SOCIETIES,

viz, the Western Society of Engineers (Chicago), the Engineers' Society of Western Pennsylvania (Pittsburg) and the Engineers' Club of Philadelphia (Philadelphia). See also Appendix G (a).

Society.	Year.	Members.	Pages in Journal.	Annual Cost per Member. Total. Gross.*	Total. Gross, less Sales.†	Total. Net.‡	Per 1000 Pages. Gross.*	Per 1000 Pages. Gross, less Sales.†	Per 1000 Pages. Net.‡
Association	1899	**1475**	**958**	**$1 72**	**$1 02**	**$0 78**	**$1 80**	**$1 06**	**$0 81**
Cleveland§.........	"	185	....	....	....	0 00	....	....	0 00
Chicago	1898	432	822	5 40	4 42	0 45	6 57	5 38	0 55
Pittsburg	"	363	436	2 28	2 02	1 80	5 23	4 63	4 13
Philadelphia	1899	436	424	3 10	2 90	1 37	7 31	6 84	3 23

*Cost of composition, paper, presswork, binding, illustrations, etc.
†Gross cost, less receipts from sales of and subscriptions to JOURNAL.
‡Gross cost, less receipts from sales, subscriptions and advertisements.
§The Civil Engineers' Club of Cleveland, a member of the Association, and one of its four original Societies.

APPENDIX G (a).

MEMBERSHIP.

Association	1475
Chicago	432
Pittsburg	363
Philadelphia	436

Pages in Journal.

Association	958
Chicago.	822
Pittsburg	436
Philadelphia	424

ANNUAL COST

Per member per 1000 pages.

Gross.

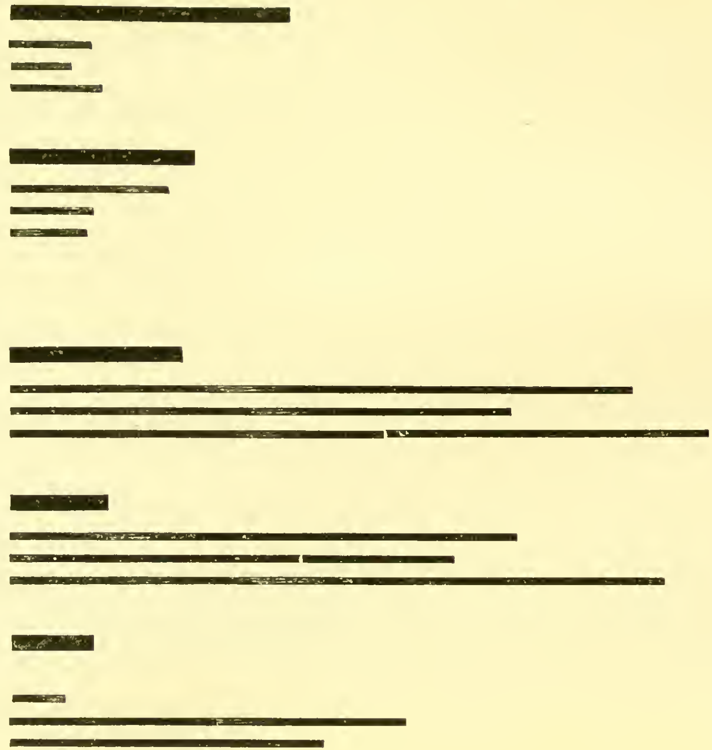
Association	$1.80
Chicago	6.57
Pittsburg	5.23
Philadelphia	7.31

Gross, less sales.

Association	$1.06
Chicago	5.38
Pittsburg	4.63
Philadelphia	6.84

Net.

Association	$0.81
Cleveland	0.00
Chicago	0.55
Pittsburg	4.13
Philadelphia	3 23



Report of Auditors.

Boston, Mass., February 5, 1900.

The undersigned, having been requested by the retiring Chairman of the Board, Prof. George D. Shepardson, to audit the books and accounts of the Secretary for the year 1899, would report that the books have been correctly kept and in a businesslike manner, that satisfactory vouchers have been shown for the expenditures and that the balance on hand December 31 was $1866.34.

S. E. Tinkham,
Henry Manley.

ARCHIBALD JOHNSON.

Member, Civil Engineers' Society of St. Paul.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION
OF
ENGINEERING SOCIETIES.
Organized 1881.

VOL. XXIV. FEBRUARY, 1900. NO. 2.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

ENGLISH EXPERIMENTS ON THE BACTERIAL TREATMENT OF SEWAGE, WITH AN ACCOUNT OF THE WORK DONE AT MANCHESTER, ENGLAND, DURING THE PAST YEAR.

BY PROF. LEONARD P. KINNICUTT, DIRECTOR OF DEPARTMENT OF CHEMISTRY, WORCESTER POLYTECHNIC INSTITUTE.

[Read before the Boston Society of Civil Engineers January 24, 1900.*]

THE bacterial treatment of sewage is the endeavor to obtain, under control and supervision, results which are everywhere being produced in nature by agents which have been at work ever since life first appeared in the world. It is an attempt to carry on, under the best possible conditions, those processes of nature by which dead vegetable and animal matter is continually being changed into mineral substances. The process, though often talked of as a new discovery, is as old as life itself, and the science of bacteriology has given us no new method, but has explained to us the steps by which the results are obtained. In fact, all along we have been purifying sewage bacterially, but it is only a generation since the first scientific investigation on sewage purification was published.

In 1870 the first report of the Royal Commission on the best means of preventing the pollution of rivers was made, and in this classical report, as Dr. Percy Frankland has recently said, we have not only the first indications of how sewage purification should be carried out on scientific lines, but also how the real purification of sewage must be conducted.

The truth of this statement is shown in the following paragraphs taken from that report:

*Manuscript received March 2, 1900.—Secretary, Ass'n of Eng. Socs.

"The process of filtration through sand, gravel, chalk or certain kinds of soil, if properly carried out, is the most effective means for the purification of sewage.

"Filtration properly conducted results in the oxidation and transformation of offensive organic substances in solution, as well as the mere mechanical separation of the suspended matter, which, when in motion, the sewage carries with it.

"With a properly constituted soil well and deeply drained, nothing more would be necessary than to level the surface and to divide it into four equal plots, each of which in succession would receive the sewage for six hours. In this way the sewage of a water-closet town of 10,000 inhabitants could, at a very moderate cost, be cleaned upon five acres of land."

The above statements of Frankland, based on laboratory experiments, received very little attention, and the only methods which were considered by sanitary engineers as practicable on a large scale were either the so-called method of sewage farming, or the treatment of sewage with chemicals.

Sewage farming was based on the idea that plant life, of itself, was capable of decomposing the complex organic compounds contained in sewage and that their capacity to do this work was almost without limit, consequently sewage could be applied continuously to cultivated land, and, if vegetation was not drowned out, purification would take place.

Treating sewage with chemicals was an attempt to remove not only suspended decomposing substances, but also those which were in solution, it being believed that certain chemical substances, like iron or aluminum hydrate, had the property of uniting with the soluble organic substances to form insoluble compounds, and that thus, by using chemicals, all the polluting matter in the sewage could be removed.

We now know that it is neither plant life in the one case, nor chemicals in the other, that removes soluble putrifying substances, but that the purification is caused by those minute forms of vegetable life which we call bacteria, and the great work achieved by the Massachusetts State Board of Health was to show that sewage could be purified on a large and practical scale by these agents. The publication, in 1890, of their work on the purification of sewage and water was epoch-making as regards the treatment of sewage. This report is too well known to you all to require any but the slightest mention. It was the results of the investigations of such men as Mills, Drown, Stearns, Sedgwick, Hazen, and showed what had been partially proved in the laboratory, that

under the proper conditions bacteria were able to destroy all of the organic matter in sewage. The proper conditions were suitable material on which the micro-organisms could be retained, surrounding these organisms at certain intervals with air, and providing periods during which the micro-organisms could rest. The combination of these conditions, as worked out by these men, is now known under the name of Intermittent Filtration of Sewage. The suitable material was sand four to five feet in depth, and the surrounding of the bacteria with air at definite intervals and allowing periods of rest was accomplished by underdraining the sand and by allowing the sewage to flow through the sand six hours out of each twenty-four.

Working in this way it was shown that 100,000 gallons of domestic sewage could be purified on one acre of sand bed area, so that danger of subsequent putrefaction was removed, and that with from 20,000 to 30,000 gallons per day the product obtained was, as far as chemical or bacterial analysis could show, as pure as spring water.

Valuable as these results were, they still left unsettled a number of important points. How could the sewage of cities be purified on a practical scale where large tracts of sandy soil did not occur? How could the sewage be treated where the separate system of sewers was not in use, and storm water was carried off by the sewers? Could sewage containing large amounts of manufacturing refuse be treated bacterially?

The quantity of sewage that could be treated by intermittent filtration with continuous success had been shown not to be over 100,000 gallons per acre per day, a quantity so small as to be quite useless for towns and cities which would be obliged to construct beds with sand not *in situ*. This point was quickly perceived in England, where sand *in situ* is not of common occurrence, and the bacterial sewage work in England started with the problem, Can the amount of land required by the intermittent filtration method be so reduced that the construction of artificial bacteria beds will be a practical possibility?

The results of the investigations started by this problem have given us what is known as the contact system of treatment and the septic tank treatment, and have apparently shown not only that by combining these two methods the amount of area required for 100,000 gallons can be reduced from one acre to about one-seventh of an acre, but also that the bacterial treatment is possible with sewage containing manufacturing refuse, and have outlined how sewage containing storm water may be treated.

The first work that need be mentioned is that of Dibden and Thudicum. The experiments of the Massachusetts State Board of Health, broadly speaking, have been along lines used for the purification of water. Dibden and Thudicum argued that in sewage containing such vastly greater quantities of organic matter the bacteria should be allowed a longer time for action than could be obtained by allowing the liquid to pass through a sand bed, and that a greater amount of work could be obtained from the bacteria if the bed was allowed to remain full of the liquid for a certain number of hours. All the micro-organisms thus being kept in contact with the liquid, they would be afforded a better opportunity for changing the organic matter into mineral matter, and the area necessary for the purification might be reduced.

The first series of experiments were made at Barking on the effluent of London sewage. The sewage itself being chemically treated with lime and iron sulphate. An account of these experiments is given in the *Journal of the Society of Chemical Industry*, 1895, pp. 915 to 920. In outline they were as follows:

Coke breeze having been found to be the most suitable substance for the filling material, a bed was constructed covering one acre of land, the ground was leveled and embanked and perforated drains were laid meeting in a common trunk for discharge, which trunk could be closed and opened by a valve, so that the sewage could be kept in the bed or the bed drained, as desired. The bed was then filled with coke breeze to a depth of three feet and covered with three inches of sand. The method of using the bed was as follows:

The valve in the trunk drain was closed, the bed was filled to the level of the surface with the above described effluent, which contained about 0.7 parts albuminoid ammonia in 100,000 parts, the bed was allowed to remain full two hours and then emptied; the emptying occupying about two hours. This process was repeated three times a day except on Sundays, the bed thus being allowed to remain empty from twenty-four to thirty-two consecutive hours each week. Working in this way the bed passed on an average 1,000,000 gallons a day, including all times of rest, and the amount of purification determined from the albuminoid ammonia was from 66 to 77 per cent. The amount of nitrogen found as nitrates in the effluent was about one part in a hundred thousand. This bed, I may mention in passing, is reported, after five years' working, free from clogging and its capacity not impaired.

Though the amount of purification thus obtained did not compare with the results of intermittent filtration, the result was

surprisingly good when the amount treated per acre is considered, and seemed to show that the theory of Dibden and Thudicum as to longer and more intimate contact of the sewage with the micro-organisms was correct, and it encouraged Dibden to carry on further experiments at Sutton, England, using crude sewage.

The sewage of Sutton is what would be called a domestic sewage, and the sewage system is on the separate plan, rainfall being excluded, though during wet weather a large volume of subsoil water enters the sewers. The sewage, however, would be classed as a strong domestic sewage.

After a number of preliminary experiments had been tried similar to those made at Barking, one of the tanks that had been previously used for the chemical treatment of sewage was placed at Mr. Dibden's disposal. On the floor of this tank, whose area was 183 square yards, was laid a 6-inch drain connected with 19 lateral drains each 3 inches in diameter. The main drain was provided with a 6-inch valve so that the bed could be emptied or filled at will. The drain pipes were covered with very coarse burnt clay, and upon this was placed a layer of burnt clay 3 feet deep, the smallest pieces of which could not pass through a half-inch mesh. The total capacity of this bed was 218 cubic yards, and when filled with burnt clay it would hold 13,500 gallons.

The burnt porous clay having been inoculated with bacteria by running crude sewage slowly through it, the bed was filled on November 21, 1896 with sewage which had only been strained through a screen, to intercept the grosser particles, the flow being stopped as soon as the sewage level was within an inch or so of the top of the burnt clay. The time required for filling the bed was about 1 hour. The bed was allowed to remain full for about 2 hours and then emptied. The time occupied in emptying it was $1\frac{1}{2}$ hours. The bed was then allowed to rest for 2 hours, after which it was again filled. The rate of flow on this bed averaged about 770,000 gallons per acre per day, rest periods included. The effluent, as I have seen it, has been clear and without strong odor, and the analyses made three or four times each month from November, 1896, to March, 1898, show the "oxygen consumed" has been reduced from 4.66 parts per 100,000 to 1.77, and the albuminoid ammonia from 0.85 to 0.296 parts in 100,000, the purification equaling about 64 per cent. The amount of nitrification has, however, been low, only 0.66 parts of nitrogen in 100,000 parts of the filtrate being found in the form of nitrites or nitrates.

This series of experiments substantiated the results obtained at Barking and also proved that a far better purification of sewage

could be obtained in the above manner, without the formation of any sludge, than by any process of chemical treatment, which, at the best, only removes 52 per cent. of the total organic impurity.

The effluent obtained from crude sewage by the above plan and with a bed treating over 700,000 gallons per day per acre would, however, undergo secondary putrefaction.

Mr. Dibden at once saw this to be the case and perceived at the same time that a further purification would undoubtedly be accomplished by allowing the partially purified sewage to come in contact with a second bacteria bed; reasoning if the first bed removed 60 per cent. of the polluting matter, why would not a second remove 60 per cent. of that which still remained? The experiment was tried; the filtrate from the first bed was run onto a second bed of the same size and construction as the first, filled, however, with burnt clay all of which would pass a half-inch mesh, the method of working the second bed being exactly the same as with the first.

The result was satisfactory, for the analyses made from February, 1897, to March, 1898, showed that the "oxygen consumed" by the effluent from the first bed was reduced from 1.77 to 0.761 parts in 100,000, and the albuminoid ammonia from 0.296 to 0.169, while the nitrogen as nitrites and nitrates rose from 0.66 to 1.75 parts in 100,000. A purification of the first effluent of about 50 per cent. and of the crude sewage of over 82 per cent.

This was the beginning of what is now known as the double contact system, the action of which has been carefully studied during the past year at Manchester. The following diagram, Plate 1, taken from an enlarged drawing of a plate in the "Experts' Report on Treatment of Manchester Sewage," gives a section of two beds of the double contact system, and a ground plan of a contact bed empty, showing the underdrains, and of a contact bed full of the filling material, showing the carriers for applying the sewage.

As is seen, in the double contact system the beds must be on two levels, so that the underdrains from the first bed are at least on a level with the top surface of the second bed, and so arranged that the effluent from the first bed can be run directly onto the second bed, or into the effluent channel. The valves in the underdrains should be so adjusted that the beds can be left filled with the purified sewage, or completely emptied.

In making contact beds the ground is excavated to the depth of about 4 feet, and the sides and bottom made water-tight best by cement 6 inches thick rendered with mortar 1½ inches thick. The bottom of the beds are channeled to receive drain pipes, or the channels themselves serve as drains, being covered with perforated

TWO BEDS OF THE DOUBLE CONTACT SYSTEM

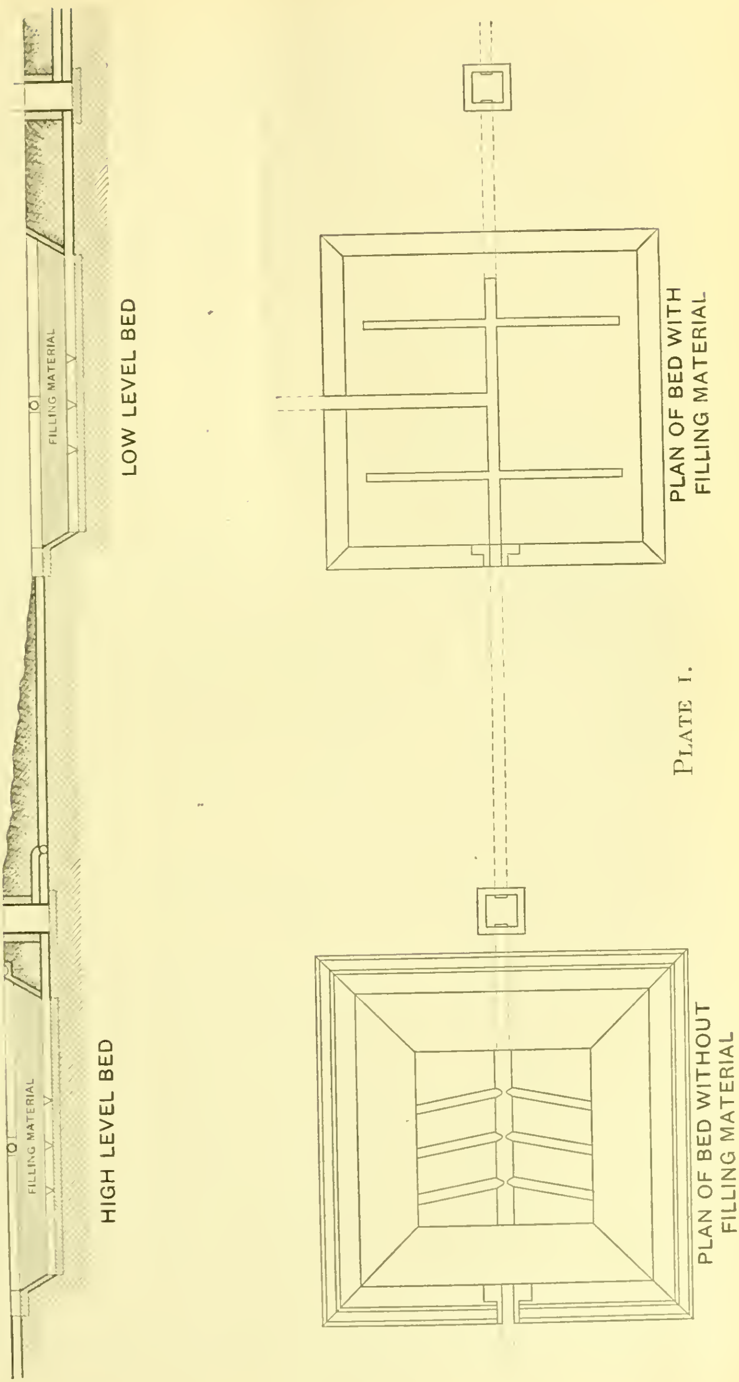


Plate I.

slabs. The effluent from these drains passes into a main drain, which is so constructed that by the use of manholes and valves the effluent can be carried from a high level to a low level bed, or can be delivered directly into the effluent channel. The construction is also such that the effluent channels can be kept full of the purified sewage or completely emptied. The sewage carriers are so arranged that the crude sewage can be delivered onto any of the beds, either high or low level, and is distributed on the beds, as a rule, by wooden carriers with perforated bottoms.

The beds are filled to a depth of 3 feet, with almost any kind of hard, porous, jagged material. Dr. Hill, of Birmingham, prefers coal; Mr. Scudder, of Manchester, clinkers or cinders. At the Manchester experimental works, coke is used. At Sutton, burnt clay. I believe the results are practically the same with the various filling materials, and all that is necessary is that the material should be sufficiently hard so as not to be easily broken down, that it should be more or less porous, so as to have a large water-absorbing area, and have a jagged surface on which the gelatinized micro-organisms can easily be retained. I am not sure but that broken iron slag would not be a better material than any of those mentioned. Whatever the material may be, it is carefully sifted and only that portion which passes a $1\frac{1}{2}$-inch mesh and is rejected by one $\frac{1}{4}$-inch mesh is used in filling the bed.

The liquid capacity of a bed so filled is a little more than one-half of its gross capacity when empty, and this is called the initial capacity of the bed. During the first two or three weeks of work of a new bed there is a marked reduction in the initial capacity, but after this time the liquid capacity remains practically constant. This initial reduction is probably due to the breaking down of the filling material, and also, as Frankland says, to the filling material becoming charged and coated over with a gelatinous slime consisting of living organisms and organic matter in the process of transformation. This reduction amounts to about one-third of the initial liquid capacity, or we can say that the constant liquid capacity is two-thirds of its initial capacity. This working capacity remains nearly constant if the bed is not overworked and is properly handled, and if the bed is allowed periods of rest, as one day in seven and a week every two or three months, there seems to be little danger of any real loss in the constant capacity or purifying power of the bed, and as far as can be ascertained the life of a bed thus worked is unlimited.

In using the contact bed system of treatment, the upper level bed is filled as quickly as possible with sewage, usually in a half-

hour, the sewage is, as a rule, allowed to remain two hours in the bed, and then if the determination of the amount of oxygen consumed or other test shows it to be desirable, it can be run onto a low level bed, or if sufficiently purified directly into the effluent channel. The time of emptying also occupies one-half hour. If the effluent from the high level bed is run onto the low level bed it is allowed to remain on the low level bed from one to two hours, as the case requires, and then passed into the effluent channel, or in a triple contact system it can be run onto a third bed on a lower level than the second bed. After a bed has been used it is allowed to remain empty three to four hours before again being filled. Used in this way the same bed can be filled three or four times a day.

As to the amount of sewage that can be purified, it has been shown by actual work that 500,000 gallons of crude strong sewage can be treated on an acre per day so that the effluent falls well within the English provisional standard,—namely, containing less than 0.148 parts of albuminoid ammonia in 100,000 parts, and 100,-000 parts consuming less than 1.43 parts of oxygen in four hours, and also that the effluent so obtained, when tested by the incubator test, shows no signs of putrefaction.*

The method of double or triple contacts has, it seems to me, placed in our hands a very delicate piece of apparatus, which might be called a bacteria machine, and which can be adapted to the work required, much in the same way as any piece of machinery in the mechanical arts. For instance, with a very weak sewage, one contact can be used, and that not of two hours, but of one hour only.

In another case, with a stronger sewage, one or two contacts, each of two hours, or one of two hours and the other of one hour, can be tried, while with certain kinds of sewage, which might come

*The incubator test so far as I know, has never been used in this country, though now being tested in my laboratory, but from experiments made in England, it appears to be one of the most satisfactory methods for determining the character of a sewage effluent. It was first used by Mr. Frank Scudder, of the Mersey and Irwell Commission, Manchester, and consists of determining the amount of oxygen consumed in three minutes by fresh effluent, then filling a bottle with the same effluent, closing it and keeping it in an incubator for seven days at a temperature of eighty degrees, then again determining the amount of oxygen consumed in three minutes. If any putrefaction has taken place the amount of oxygen consumed will show a decided increase owing to the more ready oxidizability of the products of putrefaction. If, on the other hand, the sample remains sweet, the amount of oxygen consumed will be practically the same as before incubation, or there may be a slight decrease, owing to the oxidation of impurities at the expense of the nitrates or free oxygen contained in the liquid.

down the sewers at certain intervals during the day, it would be possible in a well-arranged plant to use three contacts. This pliability of the system can be made use of for treating storm sewage, as I will show later.

I now wish to speak of a very different method of treating sewage, the so-called septic method.

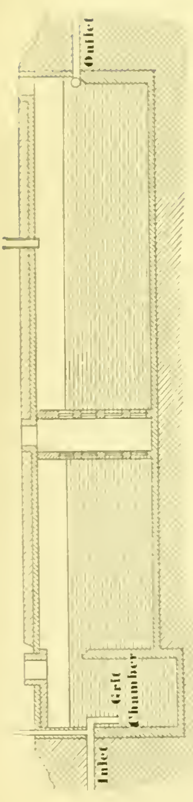
By septic treatment is meant confining the sewage for a given time out of contact with air and light. In itself it is the method of our forefathers, the cesspool, and the reactions that take place in the septic tank are similar to those which take place in cesspools, resulting in bringing into solution a large amount of suspended animal and vegetable matter. Even the use of a tank for this purpose is not new. Dr. S. Rideal (Cantor lecture, January, 1899) mentions the use, as early as 1858, of a large underground tank by a boarding school in England for the treatment of the sewage of three hundred persons, and Rudolph Herring has lately pointed out that the Mouras Automatic Scavenger, described in the "Cosmos les Mondes," December, 1881, and January, 1882, was a true septic tank.

Further, in 1891, Mr. Scott Moncrieff erected at Ashland a tank for the express purpose of liquefying the solids in sewage, in which the sewage was forced upwards over a bed of stones, and in a report of this process made by Dr. Houstan in 1893, as Dr. Rideal states, we have, for the first time, the idea suggested that the removal of suspended matter by micro-organisms should serve as a prelude to further treatment.

Notwithstanding all this, the process as a factor in the treatment of sewage of towns and cities is new, and Mr. Cameron, of Exeter, deserves the credit of having given to the world a new method.

The first experiments were tried at Exeter, England. An underground tank was constructed, Plate 2, A and B, made of cement concrete, 65 feet long, 16 feet wide and of an average depth of 7 feet, and having a cubical capacity of 53,000 gallons. The tank was covered with a concrete arch and a portion of the tank near the inlets was made about three feet deeper than the rest, and partially cut off by a low wall, forming a couple of pockets or grit chambers to retain sand, grit and road washings. The inlets were carried down to a depth of five feet below the surface so that air could not make its way down with the sewage, and also so that gases could not escape from the tank back into the sewer. The effluent outlet was also below the level of the liquid, and, to avoid any current that would be liable to carry with it any of the floating

Exeter Septic Tank. Section (A).



Section Plate 2. Exeter Septic Plant. Plan (B).

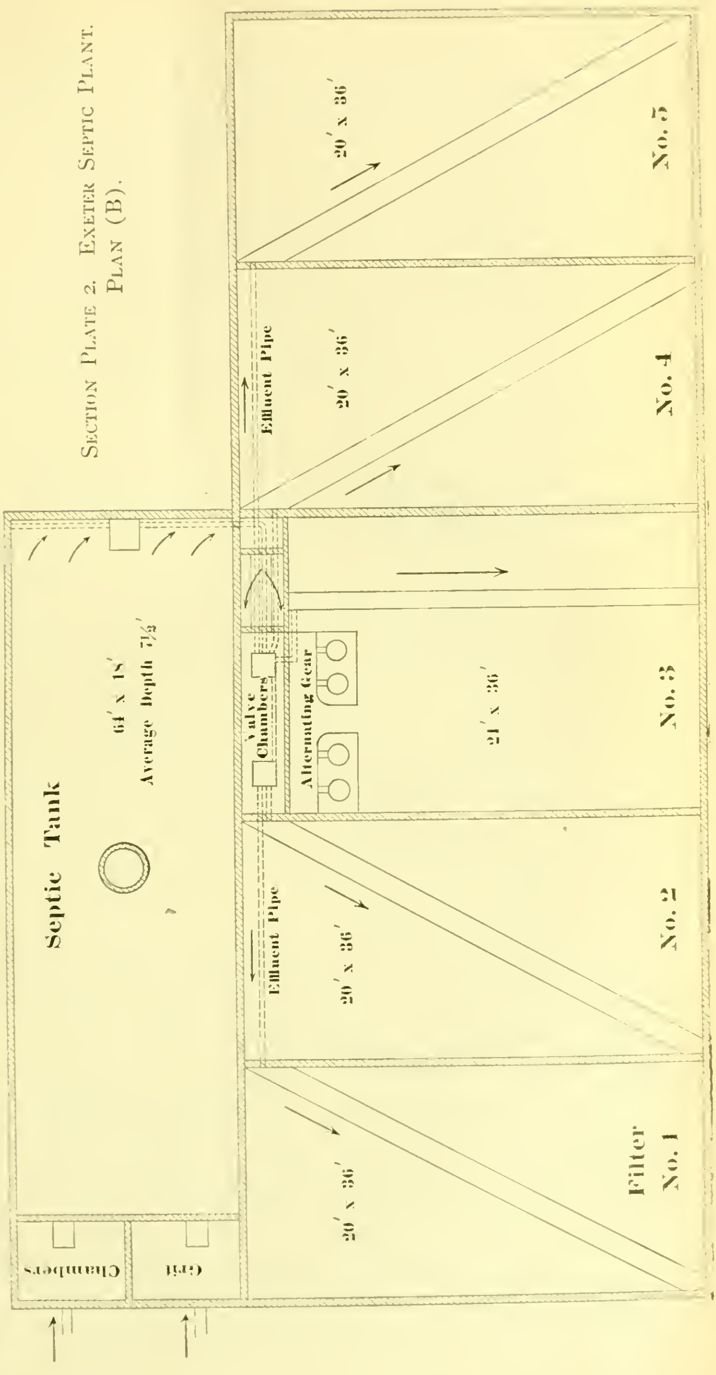


Plate 2.

matter from the surface, a cast iron pipe was carried across the whole width of the tank 15 inches below the surface, and on the lower side of this pipe there was a continuous opening about one-half inch wide. An iron pipe about 1½ inches in diameter extended out of the top of the tank to allow the escape of gases which were formed, and the sewage in the tank could be inspected by opening a manhole at one end, or descending into a manhole constructed in the center and having glass windows.

In connection with the tank were five beds, Plate 2, B, 36 feet long, 20 feet wide and 4 feet deep, constructed like the beds at Sutton, filled with crushed furnace clinker, or with coke breeze. Between the tank and the beds was the alternating gear patented by Mr. Cameron, by which the filling and emptying of the beds could be done automatically.

In August, 1896, the main sewer of St. Leonard's, a suburb of Exeter with a population of 1500 and an average daily flow of sewage of 57,000 gallons, was connected with the tank, and the above volume of sewage has been continuously passed through the tank since that time. The effluent from the tank falls over a wall about one foot high, which effects slight aeration, and then by means of the alternating gearing is caused to pass automatically on one or the other of the beds.

Visiting the plant, the effluent from the tank first strikes the attention. It is a brownish-colored fluid, free from palpable suspended matter, but does contain solid matter in a state of very fine subdivision, almost like river silt. It has an odor, but at the four different places where I examined it the odor is not more offensive than that given off from the first or second basin used in the chemical precipitation process.

The liquid in the tank is covered with a thick, floating mass, dark brownish-yellow in color, through which bubbles of gas are continually breaking. This floating mass is said to have formed during the first six or eight weeks the tank was in operation, and not to have increased much in thickness since that time. It appears to be composed of organic matter, but in fact I believe it is principally a mass of micro-organisms, and it is not till this floating mass has been formed that active septic action takes place. At the bottom of the tank there was last summer a deposit two to three feet in thickness, the accumulation of three years, as the tank has never been cleaned out. This deposit looks like sewage sludge, though it contains much less organic matter. From the iron pipe at the top of the tank issues a volume of gas which when ignited burns with a colorless flame about one foot in height. The unig-

nited gas has no very marked odor, and does not contain appreciable amounts of sulphide of hydrogen.

What are the changes that take place in this tank? The most marked change is the disappearance of the suspended matter. The analyses of Dibden and Thudicum, made at Exeter, on thirteen twenty-four-hour samples, showed that the sewage contained 24½ grains of solid matter to the imperial gallon, and that the tank effluent contained only 10.8 grains, and that consequently 13.7 grains of solid matter per gallon must have remained in the tank.

Allowing that the rate of flow had averaged 57,000 gallons per day and that the average amount of solid matter arrested by the tank equaled 13.7 grains per gallon, the total amount arrested by the tank in one year would be 24.6 tons. In August, 1897, one year after the tank had been in use, careful measurements were made of the deposit in the tank, and it was found to equal about 66 cubic yards, containing 11.66 per cent. solid matter. From the specific gravity of the deposit it was calculated that the amount of dry solid matter in this sludge equaled 5 tons. The difference between 24.6 tons and 5.5 tons, or 19.1 tons, gives the amount of solid matter which has disappeared in one year.

This result has been corroborated by many other chemists; Mr. Gilbert J. Fowler, chemist at the Manchester Sewage Works, found that from each gallon of sewage passed through the experimental septic tank at those works about 7 grains per gallon or two-thirds of the total suspended matter was removed, and this without the formation of any large amount of sludge.

How can the decomposition and disappearance of this large amount of solid matter be explained? The theory which can best be supported by known facts is, I believe, that the sewage undergoes a process of fermentation which results in the decomposition and breaking down of the more complex animal and vegetable substances, by which decomposition the greater part of the suspended matter is brought into solution. Percy Frankland, lately speaking regarding the purification of sewage by bacteria, said: "For practical purposes distinction may be made between two classes of organisms,—namely, those which are active in the absence of air, anaerobic bacteria, and those which are active in the presence of air, aerobic organisms. To anaerobic organisms are due:

First. The decomposition of cellulose and allied substances and the formation of marsh gas.

Second. The decomposition of complex nitrogenous organic matter, with the production of ammonium, hydrogen and odoriferous substances.

Third. The removal of oxygen from nitrates with simultaneous oxidation of organic matter.

To aerobic bacteria are due conversion of urea and similar substances into ammonium salts; second, conversion of ammonium salts into nitrates."

In the septic tank there would be both aerobic and anaerobic bacteria, sewage continually entering the tank, but the sewage being practically shut off from air and light it would be a most suitable environment for anaerobic bacteria, and we would expect that the first two changes noted by Frankland would be the principal ones that take place, the third change as a rule taking place in the passage of the sewage through the sewers.

The cellulose in various forms, as paper, starchy substances, woody fiber, to be disintegrated and finally liquefied; the complex nitrogenous substances, like albumen, to be broken up into simpler compounds, and those which were originally insoluble in water thus being brought more or less into solution. In these decompositions a large amount of solid matter would be changed into gaseous compounds, as ammonia, carbon dioxide, marsh gas, hydrogen and nitrogen. Of these ammonia and part of the carbon dioxide would remain in solution, while the others, being insoluble in water, would escape from the tank.

As a result of these changes we should expect the effluent from the tank to contain more free ammonia than the crude sewage, but much less albuminoid ammonia, and that the amount of oxygen consumed by the effluent to be also much less than that consumed by the crude sewage. The following analyses of crude sewage and tank effluent show the results actually obtained.

No. 1. Average of a series of analyses made at Exeter, by T. B. Perkins, Esq., public analyst.

No. 2. Average of a series of analyses made at Exeter, by Dr. G. S. Rideal.

	No. 1.		No. 2.	
	Crude sewage.	Tank effluent.	Crude sewage.	Tank effluent.
Free ammonia	4.50	7.50	3.60	4.90
Albuminoid ammonia	1.20	0.66	1.40	0.64
Oxygen consumed	4.50	3.10	6.56	4.32
Chlorine	8.00	8.10	...	...

That a large volume of gas is given off from the septic tank is seen not only at Exeter, but at Leeds and Manchester; but the only determination as to the amount (so far as I can learn) is one made by H. W. Clark, chemist of the Massachusetts State Board of Health, working with a very small experimental tank. His results indicate that from five to six-tenths of a cubic foot of gas are formed from 100 gallons of sewage.

Analyses of the gas have, however, been frequently made, and though of course it must vary greatly from time to time, the following analyses made by Dr. S. Rideal give an idea of its composition:

Carbon dioxide	0.3	per cent.
Marsh gas	20.3	"
Hydrogen	18.2	"
Nitrogen	61.2	"

It is not a long step between a closed and an open septic tank, and I doubt if it is known who first saw that similar action must take place in a large open tank as in a closed tank. The conditions, of course, in both cases must be practically the same; no free oxygen can be present in an open tank when full of sewage, and the sewage containing, as it does, a large amount of suspended matter, very little light can penetrate down from the surface. Whoever may have first used an open tank for septic action, I found them last summer being used experimentally at Accrington, Huddesfield, Leeds and Manchester. In all these places an old tank which had formerly been used for chemical precipitation had been turned into a septic tank, all the change necessary being to place the outlet so that the effluent opening should be three to four inches below the surface of the liquid, although, of course, in the building of such a tank it would be better to have the inlet also beneath the surface. In all these places the general appearance of the liquid in the tank was the same, very dark and opaque, the surface coated over with a thick layer of solid matter, and the activity of the action in the tank shown by the thousands of bubbles of gas escaping through this layer of solid matter. The effluent was of a dark brown color, containing suspended matter in a very fine state of subdivision, but neither the odor given off from the tank or from the effluent was so offensive as to prevent its use by towns or cities. That the action which takes place in the open septic tank is very similar to that which takes place in the closed tank is shown by a series of experiments made by Mr. Fowler, at Manchester. He made daily analyses for one month of the effluent from an open tank and of the effluent from a closed tank, both being supplied with the same sewage. The following table gives the average of these daily analyses. The results as seen are almost identical.

Parts in 100,000.	Open tank.	Closed tank.
Free ammonia	3.20	3.10
Albuminoid ammonia	0.50	0.51
Oxygen consumed	8.46	8.43
Chlorine	16.40	16.10

I have spoken as though the changes in the tank were solely due to direct action of bacteria. This, however, is questionable. The reactions may be, to a certain extent and possibly even to a very large extent, of a chemical nature and brought about by a class of substances known as enzymes. Enzymes are unorganized ferments, chemical substances which are the products of vegetable and animal life, and which, in minimum amounts, without being themselves used up, are able to break up and decompose large amounts of complicated and insoluble compounds. Thus the enzyme known as diastase decomposes starch; lifase, many fats; cytase decomposes and dissolves cellulose. These enzymes seem to decompose the complex organic substances by what, chemically speaking, is called hydrolysis,—the breaking up of a compound by the addition of water. In this way substances like albumen may be broken up, with the formation of nitrogen, ammonia, hydrogen, marsh gas and carbon dioxide; substances like cellulose into hydrogen, marsh gas and carbon dioxide. Many of the enzymes being the products of anaerobic bacteria, they would naturally occur in the septic tank, and a large amount of the decomposition may thus be chemical rather than bacterial.

Whatever may be the exact cause of the changes that take place in the septic tank, either open or closed, by which suspended matter is brought into solution, the process, at all times when I have seen it, was about as follows: As the sewage enters the tank, the solids gradually fall to the bottom, covered with millions of bacteria. These, or their products, the enzymes, attack the solid matter at the bottom of the tank, gradually decompose it, bubbles of gas forming which collect about the fragments, causing them to rise to the surface; where a large portion of the gas becoming detached, the solid matter again sinks, and this rising and sinking continues until the solid mass is completely decomposed. At the same time a scum begins to form on top of the liquid, and it is not till this scum is from one to two inches thick that active septic decomposition takes place. This has required at least one to two months in a new tank, but in a private letter which I have just received I am informed that at Accrington they have been able to start up active septic action in a new tank in two or three days, if some of this layer from the top of an old tank is added to the liquid. This reminds one of the action of mother of vinegar, and if the discovery is true, and there is no reason to doubt it, it is not only most interesting, but of practical importance, as it will add greatly to the efficiency of septic plant installation.

The real, practical value of the septic tank is that it destroys

suspended matter without forming any great amount of sludge or precipitate, thus having a great advantage over any chemical precipitation process. That it seems to bring cellulose into at least partial solution, thus preventing the coating over of bacteria beds, either those of intermittent filtration or contact, with a layer more or less impervious to water. That it breaks up the more complex organic compounds, forming substances that are more easily acted upon by the nitrifying bacteria than the compounds in raw sewage. There is also another advantage in the use of the septic tank that it seems to me may be of great importance. In all bacterial treatment of sewage the changes that we have followed in the septic tank take place, but in the systems of intermittent filtration beds and contact beds the second phase of purification, nitrification, is also being carried on at the same time. If in either of these systems too little air is supplied, the aerobic or nitrifying bacteria cease to work, their place being taken by the anaerobic bacteria, which are unable of themselves to finish the process, and whenever the anaerobic bacteria have obtained the upper hand, as is the case when a bacteria bed is overworked, the bed becomes foul and the product obtained is similar to a septic tank effluent. By using a septic tank, allowing the effluent to come in contact with air and then passing it onto a bacteria bed, the two phases of purification are kept separate and better work is naturally to be expected.

Dr. Percy Frankland, in his address before the Sanitary Institute at Southampton last August, says regarding this point:

"It is obvious that the indiscriminate mingling of different classes of operators in one place is entirely opposed to the principles of organization which are universally adopted in industrial establishments. If we go into any well-conducted manufactory we shall find that each class of employes carry on their work in a separate room, or even in a separate building altogether; and only in an ill-regulated establishment do we see the different classes of workmen jostling each other and interfering with each other's duties."

"In the purification of sewage, similarly, the necessity is more and more forcing itself upon experts of adopting the usual industrial plan and separating as far as possible the different classes of the myriads of microscopic hands which the sewage work has in its employ, and of providing for each a separate and suitable place in which they can carry on their particular line of business without interference."

This seems to be the opinion now held by many of our sanitary authorities, according to which the ideal treatment of sewage consists of, first, the so-called septic treatment, and then, and not till

then, of the nitrifying treatment. The successive changes which take place may be summarized as follows:

The sewage as it enters the sewer contains free oxygen, and both classes of bacteria. Oxygen being present the aerobic bacteria act upon the most easily decomposible substances, like urea, ammonia being given off. The free oxygen, however, soon becomes used up, and then conditions favorable to anaerobic bacteria prevail. Their liquefying action begins in the sewers, and is carried on under the most favorable circumstances in the septic tank, cellulose, albumen, gelatine, fats, etc., being broken up into simpler compounds. The effluent as it passes from the septic tank becoming more or less aerated by falling through the air, conditions again favorable for aerobic action are brought about, which are increased up to as great a degree as possible by intermittent filtration or contact beds; and on these beds the aerobic bacteria completely decompose the simplified organic compounds resulting from the septic tank action, with the formation of carbon dioxide, nitrites and nitrates. That there is also more or less aerobic bacterial action in the septic tank there is little doubt, and a further and more complete study of this point and many others which are not at all clear at present may give us many new ideas as to septic treatment.

Possibly I have spoken at too great length on these two new developments of sewage treatment, but, as they underlie all the best work that has been done in England during the past two years, their importance can hardly be overestimated. To-day in England you see on every side experiments being made along the lines above mentioned. Huddersfield, Leeds, Sheffield, Manchester have all decided that purification of sewage by chemical treatment is unsatisfactory, and that recourse must be had to bacterial treatment; and even Birmingham, which has been adding year after year acres of land to its sewage farm, is also, it is said, turning its attention in this same direction. The change is remarkable, for three years ago the advocates of bacterial methods were on the defensive. To-day the fight is over, as was clearly shown last August at the meeting of the Sanitary Institute at Southampton. This society has a membership of about 1500, including representative men from all parts of Great Britain; and at the meeting there was to be found only a single advocate for chemical treatment of sewage, and no mention was made as to the profit of sewage farming.

As I have said, experiments are being carried on all over England. The centers of experimental activity are, however, at Manchester and Leeds, and though very much may be learned by visits to both of these cities, I shall devote the remainder of my time to

Manchester, as we have there, as the results of the experiments, a fully developed plan for the bacterial treatment of sewage of a manufacturing city of 600,000 inhabitants using the combined system, and where the normal dry weather flow is 24,000,000 gallons per day.

The history of sewage treatment at Manchester is typical of that of most of the manufacturing cities of England. Until 1889 all the sewage of the city was discharged untreated into the four streams and rivers that flow through Manchester, finding its way ultimately into the Irwell. In that year Parliamentary power was obtained to divert and treat the sewage, and 95½ acres of land, subsequently increased to 165½ acres, were acquired at Davyhulme, about five miles from Manchester, for the erection of works. The scheme involved 36½ miles of intercepting and other sewers, a system of eleven tanks with a total capacity of 12,000,000 gallons for chemical treatment, a plan of dealing with the resulting sludge by eight filter presses, pumping engines, sludge wells, etc., and 36 acres of land for further treatment of the effluent from the precipitation tanks.

The works were completed in 1893. The sewage as it came to the works was screened, lime and sulphate of iron added, then passed through the precipitation tanks. It was the original intention to discharge this effluent on the 36 acres of underdrained land, but this was never really done, and the effluent, or at least the greater part, was discharged directly into the ship canal. The result was unsatisfactory from the very first; an effluent could not be obtained answering the requirements of the English provisional standard, or one which would not undergo putrefaction upon being added to the water of the ship canal.

This result is certainly an object lesson on a large scale to all who contemplate the construction of sewage plants.

It was very soon evident that something more must be done, and it was suggested that the effluent from the precipitation plant be purified by irrigation; but, as this would have required at least 1300 acres, exclusive of the roads, carriers and the usual adjuncts of a sewage farm, it never received any great amount of favorable consideration. In 1895 Sir Henry Roscoe suggested that the effluent from the precipitation tanks should be purified by treatment on bateria contact beds, similar to the method tried experimentally by Dibden at Barking on the effluent of the London sewage; and by his advice two small bacteria beds, afterwards increased to four, were built, and an elaborate series of experiments under the immediate direction of Mr. Frank Scudder were undertaken. These

beds were 18 feet long and 12 feet 6 inches wide and 4 feet deep, and were filled to the depth of 3 feet with the filling-material; one with coke, one with cinders, one with burnt clay and one with coal. The result of these experiments was, briefly, that cinders, on the whole, were found to be the best material, and that an effluent answering to the English standard and one that would not undergo subsequent putrefaction could be obtained by passing the effluent from the precipitation process at the rate of about 700,000 gallons per acre per day on prepared bacteria single contact beds.

While the experiments under Mr. Scudder were still being carried on Mr. Meade, the city surveyor, though expressing his confidence in the results that had been obtained, presented to the Committee on Drainage, March 1, 1896, a plan for carrying the effluent from the precipitation tanks 15½ miles in a covered conduit to the tide waters of the Mersey at a cost of about $1,300,000, and recommended the plan for adoption as solving for all time the sewage problem.

This plan, however, was not accepted by the city of Manchester, and in May, 1898, a commission was appointed, consisting of Baldwin Latham, Esq., engineer; Dr. Percy L. Frankland, biologist, and Dr. W. H. Perkin, chemist, to advise regarding the three plans above mentioned, or on any "alternative scheme which may be put before them or which they may themselves recommend."

Regarding the three plans that had been proposed, land irrigation, the culvert scheme, bacteria filters, only the latter received favorable consideration; and as this involved the previous treatment of the sewage with chemicals and the disposal of 190,000 tons of sludge annually, it was felt to be of the highest importance to undertake an experimental investigation to see if it was not possible to apply the bacterial process directly to the crude sewage.

The investigations which were thus undertaken were on a sufficiently large scale to be classed not as laboratory, but as field experiments, and it is on this account, as well as on account of the thoroughness and ability with which the work was carried on, that the experiments are of the greatest practical importance. The experiments were under the direct charge of Gilbert J. Fowler, Esq., chemist of the Manchester Sewage Works, and it is due to his personal kindness, as well as to the report of the hearings before the local Government board, and the final report of the commission, dated October, 1899, that I am able to give an account of this work. In giving details and results of the investigation I have taken the liberty of quoting very freely from this last report.

The experimental plant used at Manchester can be divided into

three parts, the bacteria bed section, the septic tank installation, the Roscoe filters.

THE BACTERIA BED SECTION.

This section, as shown by Plate 3 (taken by permission from the experts' report), consists of one small settling tank, one large tank, 300 by 100 feet, formerly used as a chemical precipitation tank, but changed by the experts into an open septic tank, and five bacteria beds. These beds, A, B, C, D, E, are constructed with 6-inch concrete sides and bottoms, rendered with cement mortar $\frac{1}{2}$ inch in thickness, the sides having a slope 2 to 1. A and C are on the same level, B, D and E on lower levels. The first four are 33 feet 6 inches square on top, 17 feet 4 inches on bottom and are 4 feet deep. Bed E is much smaller, 12 feet square on top, 3 feet square on bottom and 4 feet deep. The bottom of the beds is channeled to receive 6-inch and 2-inch drain pipes, butt-jointed and perforated, with their tops level with the bottom of the beds. These drains are so arranged that the effluent can pass from either of the high-level beds A or C to any of the low-level beds, or pass from any of the beds directly into the effluent channel. When the liquid is drawn off from the beds, the drains, by an arrangement of manholes and valves, can be kept full of the purified sewage or be completely emptied.

The sewage can be delivered directly upon any of the beds, and is distributed through wooden troughs, perforated at the bottom; one main trunk, with six branches, for each bed.

The beds are filled with clinkers to the depth of 3 feet: A with clinkers passed by a 3-inch mesh, rejected by a 1-inch mesh;* B with clinkers passed by a 1-inch mesh, rejected by a $\frac{1}{4}$-inch mesh; C with clinkers passed by a $\frac{3}{4}$-inch mesh, rejected by a $\frac{1}{4}$-inch mesh; D with clinkers passed by a $\frac{1}{2}$-inch mesh, rejected by a $\frac{1}{8}$-inch mesh; E with clinkers passed by a $\frac{1}{2}$-inch mesh, rejected by a $\frac{1}{8}$-inch mesh.

The beds being filled only to the depth of 3 feet, and the slope of the sides being 2 to 1, the effective superficial area of the four beds A, B, C and D is about one-seventy-sixth of an acre.

SEPTIC TANK INSTALLATION.

This part is very similar to the septic tank plant at Exeter. The tank is 40 feet long, 12 feet wide, 9 feet 2 inches deep, having an arched roof in which are placed airtight manholes for inspection and an iron pipe for the escape of gases. The five beds have an average superficial area of 294 square feet, and are filled to the

*The filling material in A was removed in the summer of 1899, and broken up so that it would pass a $\frac{3}{4}$-inch mesh, rejected by a $\frac{1}{8}$-inch mesh.

EXPERIMENTAL CONTACT BEDS, MANCHESTER.

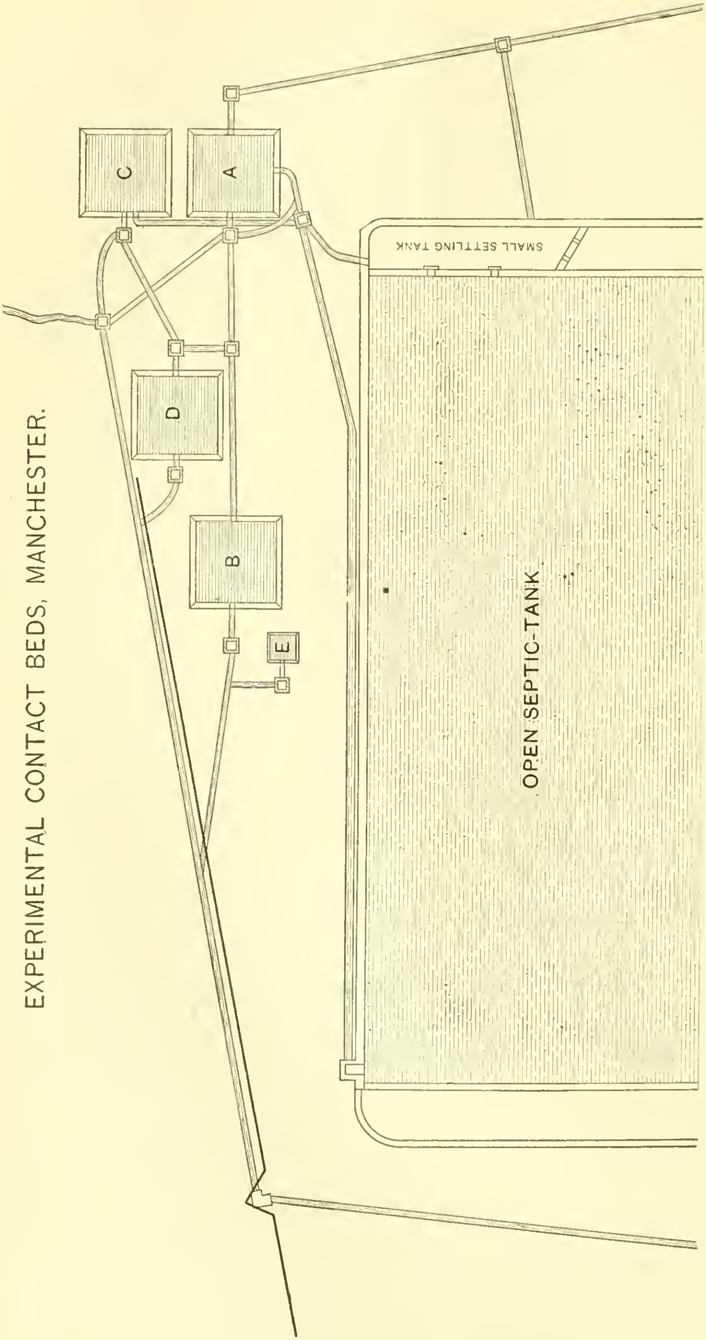


Plate 3.

depth of 4 feet, as follows, from the bottom upwards: 1 foot in depth of clinker to pass 3-inch mesh, and rejected by 1-inch mesh; 2 feet 9 inches in depth of clinkers pass a $\frac{3}{4}$-inch mesh, rejected by a $\frac{1}{8}$-inch mesh; 3 inches in depth, of residue from above siftings, which will pass a $\frac{1}{8}$-inch mesh.

THE ROSCOE FILTERS.

This consists of two of the original filters constructed under the direction of Sir Henry Roscoe, and which have already been described. They were used by the experts for experimenting with the effluent from the chemical treatment.

EXPERIMENTS WITH THE BACTERIAL BED SECTION.

The sewage used in these experiments could be applied in three different conditions:

Crude Sewage. Sewage which had only been screened to remove the grosser particles.

Settled Sewage. Sewage from which a large amount of suspended matter had settled out by allowing the sewage to remain in the small settling tank.

Saptic Sewage. Sewage which had undergone septic action in the large open septic tank.

The first series of experiments were made with settled sewage. The sewage was allowed to flow from the sewer into the settling tank and to remain there for one hour, and during the later experiments a small wooden partition was placed in this tank to keep back as far as possible all suspended matter.

Bed A was then filled with settled sewage, which was allowed to remain from one to two hours. A was then emptied, the effluent being run onto bed B, which remained full from one to two hours. This constituted the second contact. Each bed took about three-quarters of an hour to fill and three-quarters of an hour to empty, the discharge being made to take place at a uniform rate by regulating the exit valve. Samples were taken every five minutes, and the sample analyzed was a mixture of these portions. Before refilling the same bed it was allowed a period of rest varying from three to five hours.

During the first week these two beds were used, September 16 to September 21, 1898, they were filled only once a day; from September 21 to October 26 twice a day, and from October 26 to November 16 three times each day. The average holding capacity of these beds is about 3500 English gallons. The amount of sewage put on bed A with three fillings a day would be 10,500 gallons, and, as the efficient superficial area is one-seventy-sixth of an acre, this

equals 798,000 gallons per acre. With double contact, however, the effluent from A runs onto the bed B, having approximately the same holding capacity as A. Consequently the amount treated in these experiments, with three fillings a day and double contact, is 399,000 English gallons, or 478,000 American gallons, per acre.

The daily analysis of the effluent while the settled sewage was running through the beds at the above rate shows considerable variation, and while on certain days both the albuminoid ammonia and the oxygen consumed is above the English provisional standard (albuminoid ammonia 0.143 parts, oxygen consumed 1.43 parts, in 100,000 parts effluent), yet in the great majority of cases it was below this standard, and showed little tendency to putrescence, as indicated by incubator test. The average of the daily analyses gave 0.101 parts albuminoid ammonia and 1.4 parts oxygen consumed, the settled sewage at the same time containing 0.377 parts albuminoid ammonia and consuming 4.8 parts oxygen.

Encouraged by these results, experiments with crude sewage were tried. From November 16 to December 14 the beds were filled once a day with crude sewage and twice a day with settled sewage, and from December 14 to February 7, 1899, three times a day with crude sewage. After December 23 there was only one day when the oxygen consumed was above 1.43, and during the whole of the eight weeks only six times when the albuminoid ammonia reached 0.143 parts. The incubator test for the greater part of the time was most satisfactory. The average of the daily analyses of the effluent from December 14 to February 7, 1899, gave 0.094 parts albuminoid ammonia and 1.08 parts oxygen consumed. The crude sewage, albuminoid ammonia 0.36, oxygen consumed 6.6 parts.

These results are better than those obtained with settled sewage, and are probably due, as the experts remark, to the fact that the efficiency of the beds had increased by use.

On February 7 the effect of four fillings a day was tried; first with crude sewage, but, as at the end of a week the surface of bed A showed signs of clogging, settled sewage was substituted for crude sewage. The result of four fillings per day, equaling 637,000 American gallons per acre, were not so satisfactory as the results of the previous experiments, the albuminoid ammonia averaging 0.147, the oxygen consumed 1.41; the sewage containing 0.56 albuminoid ammonia and consuming 7.5 parts oxygen.

When, however, the effluent from the second contact bed B was run onto bed E, thus using triple contact, the albuminoid

ammonia in the effluent from bed E was only 0.09, and the oxygen consumed fell to 0.824 parts. These results give a good idea of the effect of multiple contacts.

The conclusions that can be drawn from the above experiments are that crude sewage containing trade refuse, and an amount of organic matter corresponding to about 0.4 parts albuminoid ammonia and 6.5 parts oxygen consumed, can be purified by double contact on prepared bacteria beds at the rate of about 500,000 gallons per day per acre, so that there is very little trouble to be expected from secondary putrefaction, but that, run at the above rate, there will be days when such putrefaction may take place.

The possibility of increasing the amount treated above 500,000 gallons per acre per day, and at the same time obtaining even a more satisfactory effluent than the one just mentioned, was next carefully considered by the commission. At the first presentation of the Manchester sewage problem the commissioners considered the possibility of turning to account the large and costly system of tanks already existing at Davyhulme, and it was decided to use one of the large tanks as an open septic tank, believing that the sewage, after having undergone the anaerobic changes, could be purified at a much more rapid rate on the bacteria contact beds.

On February 16, 1899, raw sewage was allowed to flow through one of the large precipitation tanks, 300 feet long, 100 feet wide, 6 feet 3 inches deep, holding about 1,100,000 gallons, at the rate of 1,700,000 gallons per day. Under these conditions, according to the commissioner's report, "the contents of the tank soon became black, and bubbles of gas began to rise, often accompanied by masses of sludge from the bottom, which on still days formed a scum which nearly covered the surface of the liquid;" and I may mention that when I saw this tank last summer the whole surface was covered with a thick, dark yellow layer one-fourth of an inch to an inch in thickness, and also at that time, although the tank had been in operation for six months, the only amount of sludge which could be perceived was immediately beneath the inlet penstocks. An enormous amount of insoluble matter must have been brought into solution by the anaerobic bacteria during the six months the tank had been running. On April 27, when it was perceived from the gas given off in the tank that active septic action had begun, the effluent was run onto bed A, and from there onto bed B. The results were not at first satisfactory, although for the most part, according to the reports, the final effluent as a rule complied with the English standard. The commissioners attribute this rather unsatisfactory result to the fact that these beds had been

accustomed to fresh sewage. On June 1 the effluent from the open septic tank was run onto contact bed C, and then onto bed D. These beds had been constructed later than the previous beds mentioned, and had from the middle of the preceding April received two fillings a day of settled sewage. Four fillings were now made each day, using septic tank effluent, the quantity thus treated equaling about 700,000 American gallons per day.

As a result, according to the report of the experts, not a single effluent was found to be putrescible by the incubator test, and every one was within the limits of the English provisional standard.

The following table, taken from the experts' report, shows the average of the results obtained from July 12, 1899, to September 15, 1899. First, the analysis of the effluent from the septic tank; second, the effluent from the first contact bed; third, the effluent from the second contact bed. The table shows, therefore, not only the degree of purity of the final product, but also the amount of impurities taken out in the different stages of the process.

I have also, for the sake of comparison, given the average analysis of the sewage and of the effluent obtained by intermittent filtration at Marlboro, as stated in the last report of the Massachusetts State Board of Health, 1898, where the amount of sewage treated is about 90,000 gallons per acre per day. The per cent. of impurities removed, as determined by the amount of albuminoid ammonia and oxygen consumed, is also given.

Analysis of effluent. Parts in 100,000.

	Free ammonia.	Albuminoid ammonia.	Oxygen consumed.	Nitrogen nitrites, nitrates.	Chlorine.
MANCHESTER.					
Septic tank	3.20	0.390	7.00	...	16.4
First contact bed	1.80	0.170	2.20	0.052	16.0
Second contact bed	0.51	0.075	0.69	0.870	15.7
MARLBORO.					
Sewage	1.90	0.4600	2.59	0.15	4.91
Effluent	0.62	0.0328	0.34	0.56	5.00
PER CENT. REMOVED.					
Manchester	84.1	75.2	90.1	...	...
Marlboro	64.6	92.0	86.9	...	...

As is seen by the above results, there is no question but that the intermittent filtration method gives a purer product than is obtained by combining the septic tank with double contact beds, and, further, judging by the amount of albuminoid ammonia, the only fair factor to take. The percentage of organic matter removed by intermittent filtration beds, when treating sewage at the rate of

90,000 gallons per acre per day, is greater than by double contact beds treating 700,000 gallons per day. What I think is shown by the above results is that by the Manchester method, if I can so call it, a satisfactory effluent, one containing so little organic matter as to be non-putrescible, can be obtained on one-ninth the area required by intermittent filtration beds.

Regarding the experiments made with the other sections of the experimental plant, it is only necessary to say as regards "the Roscoe filters" that they have been worked during the whole period of the investigation, receiving the effluent from the precipitation tanks, and from the last report their efficiency remains at least at 700,000 gallons per acre per day.

CLOSED SEPTIC TANK INSTALLATION.

Experiments with the closed septic tank installation were begun in November, 1898. They confirmed the results obtained at Exeter as regards the time of bringing a tank into full septic action, the destruction of organic matter and the changing of complexed organic compounds, so that they are more easily attacked by the aerobic bacteria. But, more important than this, the experiments showed the decided advantage of the double contact system over the single contact method, for when the effluent from the septic tank was treated at the rate of 700,000 gallons per acre per day on one bacterial bed of a given unit area it did not give a product that fell within the English standard, though it showed little tendency to putrefaction; while if the same effluent was passed first onto one bed of one-half the given unit area, and then onto a second bed of one-half the given unit area, the final product was well within the English standard. Or, in other words, if from an unit area two beds are made, and the effluent from the septic tank is run first onto one bed, and then onto the second bed, a far purer product is obtained than when the effluent is run onto the undivided unit area.

This is clearly shown by the analyses made by Mr. Fowler of the effluent of the septic tank after having passed through an undivided unit area, and of the same effluent after having passed on an unit area divided into two beds.

The following table gives the average of the results of daily analyses made during the month of March, 1899:

	Unit area undivided	Unit area divided into two parts.
Albuminoid ammonia	0.155	0.075
Oxygen consumed	1.650	0.690
N. as nitrites	0.058	0.056
N. as nitrates	0.382	0.814

This direct proof of the great advantage of dividing a unit area into two parts, or of the double contact system, is of the greatest value, and I think it will have a very important bearing on all future sewage work.

The results, in brief, obtained from the experiments I have described seem to show:

First. That crude sewage, containing manufactory waste, can be purified so that it will, as a rule, give a non-putrescible effluent when treated at the rate of about 500,000 gallons per day per acre, according to the double contact method.

Second. That if crude manufacturing sewage is subjected to septic action it can be treated at the rate of about 700,000 gallons per acre per day by the double contact system, with almost positive assurance that the affluent will not be putrescible.

Third. That if crude sewage is subjected to septic action it cannot be treated at the rate of 700,000 gallons per acre per day as satisfactorily by the single contact system as by the double contact method.

Fourth. That the effluent from the chemical precipitation process can be treated at the rate of at least 750,000 gallons per day per acre by the single contact system.

For a town or city that has the separate system of sewers these results are of great value, but a very important question still remains to be answered. How can the double contact system, or in fact any method of bacterial treatment, be adapted for a town or city where the normal flow of sewage may be multiplied four or six times by a few hours of heavy rain?

Experiments have been made, and are being made, at Manchester and many other places in England as to the treatment of storm sewage, and the results furnish a most interesting study to both the chemist and the engineer. I cannot at this time take up this subject, as any adequate presentation of the treatment of storm sewage would require a whole evening. I will merely say that the experiments made at Manchester seem to show:

First. That sewage during the first hour or so of a storm, being stronger than the normal sewage, cannot be treated at an accelerated rate on the double contact beds, but that the sewage after that time, as it becomes diluted with the storm water, can be treated at an accelerated rate on double contact beds by first shortening the time of contact, and then by allowing only one contact in place of two.

Second. That when a storm is over and the ordinary treatment is resumed the bacterial beds show no decrease of purifying efficiency in consequence of the previous accelerated treatment.

The information gained by all the experiments that have been conducted at Manchester, and of which I have given an outline, have fully convinced the commission that both the dry weather flow and the storm weather flow can be successfully treated by the combination of the septic treatment with contact bacteria beds, and they have recommended the following plan for the city of Manchester, based on a normal flow of 30,000,000 gallons, though the present flow is only 24,000,000, and a storm weather flow of over 90,000,000.

To construct four additional tanks, each of the cubical capacity of 1,000,000 gallons, to serve as roughing tanks, through which the sewage is to be passed rapidly. To raise the walls of the eleven tanks now at Manchester so that their capacity shall be increased from 12,000,000 to 15,000,000 gallons. To make 120 contact beds, each of one-half acre superficial area, to be built in pairs, high-level and low-level. The carriers to be so arranged that the sewage can be delivered on any one of the 120 beds, and the drains so constructed that the effluent from the high-level beds can be delivered onto the low-level beds, or directly into the effluent channel. To make 25 acres of single contact beds, to be used for the treatment of the storm water sewage, not dealt with by the 120 contact beds.

The usual treatment of sewage with this plant would, it seems, be somewhat as follows: As the sewage arrived at the works it would be screened and passed through the four roughing tanks for the further removal of mineral matter in suspension, then passed slowly through the eleven large tanks, whose cubical capacity is 15,000,000 gallons, so that the flow occupied about twelve hours, these tanks thus serving as open septic tanks. The sewage from the open septic tanks would then, after slight aeration, be passed on to the double contact beds.

The commission believes that in this way 30,000,000 gallons of normal sewage can be treated per day, so that the effluent will fall well within the English standard, and show no signs of putrescence; and that in providing 60 acres for a contemplated flow of 30,000,000, when experiments have shown that one acre is capable of treating 700,000 gallons per day, sufficient margin has been allowed for periods of rest and for necessary repairs.

The procedure in case of storms would be somewhat changed. The double contact beds would be worked at about their usual rate, till it was shown by the chlorine number that the sewage was diluted with rain water: the rate would then be increased proportional to the dilution, first by shorter contacts and then by single contacts in place of double. As the volume of storm sewage in-

creased part of the sewage would be cut off from the eleven septic tanks, passing only through the four roughing tanks, and from them directly onto the 25 acres of storm bacterial beds, where it could be applied at the rate of 2,500,000 gallons per acre per day, as it has been shown that with very dilute sewage this very large amount can be successfully treated for short periods.

After the storm was over and the flow had again fallen to normal the sewage would be treated in the usual way, and the storm bacterial beds be allowed to rest, receiving only an amount of sewage necessary to maintain their efficiency.

In this way, even without shortening the time of contact or number of contacts on the 120 regular contact beds, it is believed that a storm flow of 90,500,000 gallons per day could be successfully treated.

I have tried to state in the time at my disposal the outline of recent experimental work in England on the bacterial treatment of sewage, and though future experience and study will undoubtedly modify many of the views now held, I think the work I have mentioned shows that it is possible to purify not only domestic sewage, but the sewage of manufacturing towns, and sewage diluted with a large amount of storm water, by bacterial methods, and on areas which make the bacterial treatment possible for towns and cities where the amount of suitable soil for intermittent filtration beds cannot be obtained.

How far these methods are applicable for towns of Northern New England, where the winter temperature of the sewage is at least ten degrees lower than it is in England, will undoubtedly be determined by work done in America, and the opinion of the Massachusetts State Board of Health, based on experiments which are still being carried on, will be of the greatest value.

POLLUTION OF STREAMS, WITH SPECIAL REFERENCE TO THE CHICAGO DRAINAGE CHANNEL.

ADDRESS BY B. H. COLBY, RETIRING PRESIDENT OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read at the Annual Dinner December 20, 1899.*]

AMONG the most vital questions of the day, that concern the present and future welfare of our cities, none is more important than the question of water supply. Very few, if any, of our centers of population are so fortunately situated as to possess an abundant supply of pure water, free from contamination. Cities that have thought themselves to be thus favored have found that, under conditions of increased population at home or in other cities, not always or necessarily near to them, their supposed water supply, far from being pure and wholesome, has become polluted, unfit and dangerous for human consumption. Particularly is this true of all our cities depending upon streams for their water supply. The day has gone by when it is necessary to support with argument before engineers the proposition that pure water cannot be drawn from a stream flowing through a settled country and receiving the dejecta of its inhabitants. It has now become a question of how long and to what extent such conditions will be allowed to prevail before the evil consequences thereof are recognized by the majority of our people, and the proper remedies demanded and applied.

To my mind, there is one question in connection with water supply paramount to all others, which should first be decided by the people of the United States, before our cities are required to adopt and put into operation plans for water supply or sewage disposal. I mean the general question as to whether our rivers and streams are to be, in the future and for all time, the protected sources of pure water supply, from which all communities may safely draw, or whether they are to be open channels into which every community may discharge, without question or fear of legal opposition, manufacturing refuse, offal and filth of every kind and description. Ultimately, there can be no middle ground, as at present. Our streams will be pure, or they will be foul. If the people decide that they are to be foul, what follows? Evidently they cannot then be sources of water supply. Where, then, are we to look for our water? There remain only two sources, lakes and wells. It is possible to supply from the great lakes upon our northern border a very considerable territory. In many of our States numerous small

*Manuscript received January 25, 1900.—Secretary, Ass'n of Eng. Socs.

lakes are to be found that contain ample supplies of water which, under proper legal supervision, can be maintained in a state of purity. In rural districts wells and springs must continue to furnish the inhabitants with water. With large inland cities located upon polluted streams, or upon no streams at all, the latter case being very rare, the problem of water supply will become very difficult. In certain sections, where such a condition prevails, water may be secured by means of artesian wells, but in many localities, as in St. Louis, artesian wells furnish either salt water or water impregnated with various mineral salts, rendering it unfit for domestic use. Such cities will, by reason of their geographical position and the fouling of their natural source of water supply, be compelled to convey water in most cases from great distances, and at an expense which cannot fail to be a great burden upon their people. Naturally, in such cases, the first thing thought of, and in most cases the last thing done, is to resort to filtration. As to what results may ultimately be accomplished by improvements upon present methods of filtration, the best-informed upon the subject do not now feel warranted in making conclusive statements of their opinions. We know that much can be accomplished in this direction. We know that nearly all suspended matter and a very large percentage of bacteria may be removed by filtration. We know that soluble salts are not removed by filtration, but require chemical precipitation. We know also that the typhoid fever bacillus will pass through every description of filters known. We know that a certain percentage of typhoid fever bacilli are destroyed by filtration processes, but we do not yet know what that percentage is. I believe we know enough about filtration to-day to plant our feet firmly upon one unassailable proposition, and that is that all water intended for domestic consumption should be filtered. The best is none too good. Therefore, upon the proposition that our streams are to be pure, let us make them as pure as it is practicable for us to make them. First of all, to this end, we must by proper legislation prohibit absolutely the discharge of raw sewage into our streams and lakes. We must also protect them as much as is possible from surface contamination.

We are now in a makeshift stage uncertain of our ground, each city trying to make the best possible temporary provision for its own people, and I am afraid in most cases having little thought and less care for others. Granted that this is true, I do not propose to apologize to or for the American people. The condition is natural, and what might fairly be expected in a government as young as ours. In many older, and supposedly much more enlight-

ened countries, we know that there is the same spirit of self to-day, your neighbor to-morrow. Boiled down, it is but the human expression of nature's first law,—self-preservation; and, so regarding it, we recognize the almost insurmountable difficulties to be overcome by the few before the many can be made to see that nature's law of self-preservation is not restricted necessarily to individual preservation. Self-preservation may, and often does, mean the preservation of multitudes with self. It is always the case that the first conceptions of so-called natural laws as well as of human laws, are selfish. We are prone to see in our own interpretations all the possible privileges and advantages secured to us, and all the restrictions placed upon our neighbors.

Nature works out her problems in long periods of time, and we should not be despondent. It is none too soon to teach the golden rule, but it is too soon to expect the majority to follow it. The world is young, and in the future there is time. As Emerson puts it, "Man is no upstart in creation, but has been prophesied in nature for a thousand ages before he appeared; from time incalculably remote there has been a progressive preparation for him, an effort to produce him. The meaner creatures contain the elements of his structure, and point at it from every side. His limbs are only a more exquisite organization—say rather the finish—of the rudimental forms that have been already sweeping the sea and creeping in the mud; the brother of his hand is even now cleaving the Arctic Sea in the fin of the whale, and in innumerable ages since was pawing the marsh in the flipper of the saurian." Let us be patient. If it took countless ages to produce the animal man, as we all believe with Emerson it did, how many ages will it take nature to produce the intellectual part of man,—the man with the divine mind, with the broader interpretation of natural law, to whom and with whom the practice of the golden rule is but the natural expression of his being? This is dealing in futures,—a long way in the future,—but until the golden rule man is here, and in the majority, we cannot expect golden rule laws. Our lives and the lives of many generations after us will have to be lived under conditions little improved upon the present. Our problem is not how to deal in futures, but with the present. How to obtain the best possible for all living; how to make the best use of what we obtain; how to preserve the fruits of our labor for those who are to come after us. With lesser aims we are degenerates.

Now let us come back to water supply and its related subject, sewage disposal. How are we to obtain the one and dispose of the other? Must we wait for the golden rule man to be in the

majority? Shall we go about like fat oxen, feeding off the bounties of nature, receiving sustenance from her lavish hand, but returning to her nothing but our dust, content with our sleekness? Or shall we try to adapt her great resources and forces to the use and benefit of man? I hold that nature's resources and forces lie in the animate as well as in the inanimate, and that it is just as much the province of the engineer to develop, utilize and control the great animate mind forces of nature for the use and benefit of man as it is the inanimate forces. No man can be a great engineer, or great in any other profession, until he can in some measure control mind forces. A great man must be enough of a leader to secure followers; must have those behind him who are willing to back his opinions with their purses; the mind has to be led before the purse can be commanded; without the money bag engineering structures are impossible. Engineers must first of all inspire confidence in the utility and practicability of their proposals. No great undertaking was ever begun and carried to completion without confidence. Sometimes there are more who are confident of your failure than there are those who are confident of your success. Especially is this so if we leave the beaten track of common practice. But at times leave the beaten track we must, and it is my opinion that we must do so in the case of water supply and sewage disposal. Perhaps I should reverse the order, as in many cases sewage must first be taken care of before pure water is possible. This means that every city, every town and every factory which is now discharging sewage or refuse into streams or lakes must by legal enactment be made to render harmless, by proper treatment, all of their sewage and wastes before emptying the same into bodies of water which are, or which might be, used as sources of water supply. But how is this to be accomplished? I answer by Federal law. I can see no other way. We cannot rely upon state statutes or upon municipal ordinances in this matter. The majority of the people are too selfish to incur the necessary expense to protect their own lives. They are content to take their chances. Then, too, communities are justly slow in assuming great expense which, after all, only partially protects their interests, requiring for complete protection similar concerted action and expense from other communities before the benefit sought is received. The same can be said of State governments, leading us up to the absolute necessity of a general Federal law which shall require every city to pay for rendering harmless to others its own sewage before turning it into streams from which less favored cities must by necessity draw their water supplies.

To be as nearly correct as possible in my statements of existing

laws in relation to river pollution, I asked my friend, Professor W. S. Curtis, dean of the St. Louis Law School, briefly to note and comment upon such laws as he could readily find upon the subject. In substance, Professor Curtis says, "Upon the subject of pollution of rivers there is no Federal statute. Some of the States may have, but such laws would be local and of no 'interstate' effect. The English have an act called 'The English Rivers Pollution Act,' of date 1876." As to common law, Professor Curtis says, "Without doubt everywhere, in both England and this country, the common law, as distinguished from statutory enactments, protects the rights of lower riparian owners and dwellers as against those living higher up in all customary uses of the waters, including the right to have the water free from pollution; the only question is as to how far (as against how slight a pollution) the right extends. A case illustrative of this right is in 119 California Reports, page 387. The use of river waters for drinking purposes is comparatively modern; that is, in the wholesale way of water works in our great cities. In the absence of statute, and relying on common law, there is no doubt the lower river dwellers, in protection of rights to use water by water works, would have a good standing in court, as against such a wholesale pollution as that threatened by the Chicago Drainage Canal Commission; and all the more in this case because the commission is to accomplish its object by lifting the waters; in other words, by changing the natural configuration of the drainage." He adds, "There is danger in sleeping on rights while expensive and ostensible preparations were being made by the commission. If any preventive legislation follows, it will turn upon expert examination as to the probable extent of the pollution, and upon the question how far rights have been lost by postponing interference. An entirely different question is presented at lake cities, in the navigation interests involved, consequent upon the possible lowering of lake levels by the diversion."

So much Professor Curtis gives. I may add that all navigable waters in the United States are under Federal control; that no State, city, company or individual, except by Federal authority, has any right whatever to their use. Doubtless purely commercial reasons were at the bottom of this fundamental principle of Federal control at its inception. The same reasons that induced the great men who framed our Constitution to invest Congress with this regulative power as to navigation exist to-day in a tenfold ratio, and the necessity for such power is a thousand times more apparent now, after one and a quarter centuries of internal development and progress, which at the time of the adoption of our Constitution were un-

dreamed of by the forefathers. There were no large cities then. There were no polluted streams, and the question of water supply upon the scale now necessary throughout the length and breadth of the land would then, if thought of, have been believed absurd.

From the adoption of the Constitution to the present day the Federal Government has assumed a firm control over all navigable waters, and over all the land of the country as well. From time to time it has enacted laws for the use of the waters and the disposition of the land. There is a small minority who maintain, with what appears to me to be much more of zeal than of sense, that the Federal Government should not dispose of its land to individuals, but should hold it in trust for those who, in return for the privilege of occupation or cultivation, are willing to bear all the expenses of our National, State, municipal, county, town and township Governments. That the policy of the gift of homesteads by the Government to settlers and the sale to others who desire larger farms is a wise policy and approved by the great majority of our people is unquestioned. But I have never heard of any of our people advocating the gift, sale or lease of any body of navigable water lying within the borders of our country. It is impossible to conceive of such a proposition being made in seriousness, and should any unbalanced legislator have the temerity to bring a measure before Congress providing for the sale, lease or control of our navigable waters to the highest bidder such an one would raise a tidal wave of righteous indignation and protestation such as would render his residence in foreign parts convenient, if not obligatory, for all future time. But, important as the interests of navigation have become at the close of this century, and vital as the principle of Federal control of navigable waters seems to our people, we are beginning to see that there is another and more vital reason for the exercise of Federal authority in this matter. Pure water is one of God's best gifts to man. As long as there is enough for all, questions and contention as to its use do not arise, and much latitude is permitted users, but whenever great care is necessary to preserve the purity of a water supply, public safety demands that those who refuse to regulate their actions for the general good be compelled to do so.

A city has power to regulate and control its own people; a State has the same power over the city, and the general Government has the power to enact laws which all must observe. Within their own borders it is in the power of cities to establish sanitary regulations, and neglect or refusal to make adequate provision in this respect to a degree that threatens to jeopardize the health of adjacent dis-

tricts is legal ground for the State to step in and compel enactment and observance of proper relief measures. Such relief, however, is confined to one State, and, although local relief may ensue, the unsanitary condition is only too frequently transferred to another locality and, as is often the case, to another State.

The past history and present condition of water contamination in this country justifies the positive assertion that the subject will never be satisfactorily dealt with by either State or municipal law. The sooner this fact meets with general recognition by the public, the sooner will our representatives in Congress enact a general law that will protect our water supplies from pollution for all time to come. That such a law would be cheerfully obeyed by all the States I have no doubt, and that such a law will be enacted in the near future I am equally confident. Toward this end the people of St. Louis have contributed in full measure, and it is but just to add that the beginnings of the movement that will finally lead to Federal action had their origin in the Engineers' Club of St. Louis. The leaven here prepared has raised a discussion that has become national in its scope. This agitation has led, this very month, to the introduction into the United States Senate by a Senator from Missouri of a bill which is, I believe, the entering wedge that will open the way in two or three years for the passage of a general Federal law controlling the pollution of navigable and unnavigable waters and the sanitary disposal of sewage and wastes. The bill provides for the expenditure of $10,000, under the direction of the Surgeon-General of the United States Army, to investigate the pollution of streams. I believe that the bill will pass; that in due time a report of such investigations will be made to Congress; that the results obtained will be found of such practical value that additional and larger appropriations for continuing the investigations will be made, and that, when final results and reports are made, the showing as to the great necessity of Federal action will be so conclusive that the outcome will be the appointment of a joint sanitary commission from both branches of Congress to prepare and report for approval a general law to prevent the future contamination of water supplies. St. Louisans may then be justified in a feeling of pride in their efforts in helping along the good cause; but in our time of elation we must not forget that our efforts came in part from necessity, not from inherent virtue; that, had the conditions been reversed, we might have been just as apathetic as our neighbors. But I am again dealing in futures. We have no Federal law, and we are drawing our water from a sewage-polluted stream. Present conditions are bad enough, but we are menaced with a con-

dition of things that ought to raise our ire to the sticking point. A city 300 miles away is preparing to transport and to dump into our water supply at our very front door the refuse and filth from two millions of people. Think of it a minute! Conceive of it as it is; you cannot. Visit the Bridgeport sewage pumping works in Chicago, as some of you have done, and you will know that I do not exaggerate when I say that nowhere upon the face of the earth is there to be found another stream as deadly foul as is the Chicago River. Receiving as it does a large part of the surface washings and the discharge of most of the sewage of a dirty city, its pollution is still further augmented by the refuse from the largest stock-yards and slaughterhouses in the world. I wish I could cause the inhabitants of St. Louis to march in single file past the sea of nastiness pumped from the Chicago River at this point, a sea which flows away in a channel called the "Illinois and Michigan Canal," but which is, in fact, nothing but a good-sized river filled with the filthiest filth that ever flowed forth to join a stream from which other cities do and must take their water supplies. With such an object lesson there need be no sermons, no public agitation to arouse the people of this city to the danger that threatens them. Rather would it require cool heads to restrain them from doing violence to the "sewage ditch." After seeing Bridgeport and following for miles the swiftly-flowing stream of filth, no sophistry could ever induce the most ignorant citizen to believe for one moment that ten times the proposed amount of dilution from Lake Michigan could ever render this mixture fit for human throats. Neither could he be made to believe that sedimentation takes away from the mass all that is injurious to health. He has followed that stream, has seen the much-mooted sedimentation and knows of his own knowledge that death is there.

Yes, sedimentation does take place; thousands of tons of filth settle annually upon the sides and bottom of this famous ditch; canal boats pass over it and help to liberate the gases from the putrifying mass; myriads of bacteria find their birthplace there, and are borne along upon its dark bosom to the Mississippi River. Some of them, Dr. Ravold* says, find their way into the intake of our water works. Is there a man here who does not believe Dr. Ravold is right? Once in the intake there is no way to escape; they are distributed under 45 pounds pressure, to be mixed next morning with our porridge. We are now receiving the discharge of such a death-dealing stream. If the legal efforts now being made by our city officers to stop this pollution are not successful, we shall

*Bacteriologist, Health Department, St. Louis, Mo.

soon be deluged with another stream, larger and still more dangerous. It will bring into our water supply a contamination and pollution never experienced before. It will sow the germs of disease and death broadcast among our people. The stream will be broad and deep, lined with festering foulness and 300 miles long.

As engineers and as citizens let us be alive to the danger that confronts us. Our first step should be filtration. What do we lack to secure the filtration of our water supply? Can you answer it? We have competent engineers. We have the will. We have the money. What more is lacking? Power is lacking. What a confession to make. We, the people, lack power to accomplish our will. Shame upon us. But we have that reserve force within us, latent though it has been, that is all powerful. Let us exercise it. Let us send to eternal oblivion those who seek office solely for private gain; those who regularly defeat every measure for the public good. Let us make it our business to put men in our municipal assembly who work for, and not against, the interests of St. Louis. It is there, and there only, that we need power. Then let us, one and all, work to secure the permanent remedy, not ceasing our efforts until we have secured the enactment of a general Federal law for the sanitary disposal of sewage and the prevention of water pollution.

PAINTS AND VARNISHES.

By Prof. A. H. Sabin.

[Read before the Boston Society of Civil Engineers November 15, 1899.*]

Iron may be protected from corrosion in several ways. First, by imbedding it in concrete or cement. This material is strongly alkaline, and, as alkalies do not attack iron, the iron is likely to be preserved as long as the alkaline quality persists, which may be for years, especially if in a dry place; but cement is somewhat porous, as may be shown by the fact that a battery cup may be made of it as a substitute for the ordinary porous earthenware cup. It is also well known that there is a German cement-testing machine, which operates by determining the relative porosity of similar plates made of cements. If, then, cement or concrete is used under water or exposed to acid gases, which will attack the alkali in the cement, its porosity, though small, may lessen the duration of its protective effect. If, as a second method, we use a non-porous and insoluble cement, such as asphalt, we avoid this difficulty; but this method also has its limitations. For example, it cannot be used where the material may be subjected to heat, as the asphalt will melt; and, since asphalt is a viscous substance, it will not support itself, but will run off, or may be forced out of place by external pressure. Again, asphalt, which is a soft and flexible substance, owes its pliability to some mineral oily matter which it contains, and in practice those who prepare it for use almost always add to it some heavy mineral oil to increase its viscosity. This softening ingredient, though apparently insoluble and non-volatile, is only relatively so, and when it is gone the remainder of the asphalt is left as a brittle, crumbly substance of no value for the purpose for which it is used. We should, therefore, use a layer of asphalt of considerable thickness, and the ingredients should be selected and mixed by some one having proper knowledge of the subject. Except in very dry situations, and where the air has very little access, it should not be relied on for permanent protection; but there are many cases, such as those of bridge floors, where it may be the best thing available.

Both these classes of cements are, therefore, to be used only in special cases; and for nearly all such purposes we are obliged to use such coatings as are commonly classed together as paints, meaning thereby a substance as little affected as may be by air or water, and which may be spread in a thin film over the surface of the metal. Such a film should be as nearly continuous or non-porous as possi-

*Manuscript received January 11, 1900.—Secretary, Ass'n of Eng. Socs.

ble, and its value for the purpose depends on its retaining a non-porous condition for a long time. For example, a piece of metal may be coated by dipping it in melted asphalt at such heat as to secure a thin film. This film will be highly non-porous, and will resist severe acid and alkali tests; but after a brief exposure to the air it will be decomposed, and will then afford no protection, while a film of other material, inferior to it in the beginning, may retain its original degree of continuity for years and be a valuable coating.

Ordinary oil paints consist of linseed oil, sometimes more or less adulterated, mixed by grinding with a pigment, which latter is usually a mineral substance reduced to a fine powder. The object of using a pigment, aside from its color, is threefold:

First. It hardens the film, which will thus better resist abrasion.

Second. It makes it possible to apply a thicker film, which also wears longer.

Third. The particles of pigment tend to fill up the pores which are naturally present in the oil film, and thus the porosity is reduced.

The pigments used for preservative paints are few in number as compared with those used in house or other decorative painting. They may be described briefly as follows:

White Lead. This is a mixture of lead hydrate and carbonate, and is sometimes sold as a dry pigment; but more frequently as paste white lead, which is nine parts dry pigment ground with one part by weight of raw linseed oil. This may be made into a paint by thinning it with oil, and usually a little turpentine is also added. The object of the latter is not to cheapen it (indeed, at the present time turpentine is worth more than oil), but to make it work more freely under the brush and to increase the proportion of pigment in the film. This is a matter which it is very easy to overdo, and if too much turpentine is added there will not be enough oil to act as cementing material for the pigment, which will then be easily removed. White lead is especially liable to suffer in this way, since it normally takes less oil than any other pigment, and, moreover, it seems to have a natural tendency to combine with the oil. This combination causes the oil to lose its coherence, and then the surface of the paint easily rubs off. As painters say, it chalks. No doubt a great deal of the bad name of white lead is due to this excessive and improper use of turpentine, which is liked by the painter also because it makes the paint much whiter than it is when oil is used, and because it dries rapidly, owing to the volatility of the turpentine.

White Zinc is an oxide of zinc, white in color, and it requires more oil than white lead. It is less opaque; its opacity or covering capacity is usually estimated as three-fifths that of white lead. Paint made with it does not readily brush off as a powder, but sometimes seems to come off in flakes. Painters say it peels or scales. It is commonly used mixed with white lead, and the mixture seems to be better than either substance alone. Paints made with these pigments are frequently, perhaps it may be said commonly, adulterated with other white powdered substances, such as kaolin and barytes, which are not particularly harmful, and whiting or carbonate of lime, which is actively injurious. While dry these substances appear white, but when mixed with oil they seem to be transparent. They are without value as pigments, and must be regarded as adulterants. White lead and white zinc are practically the only white pigments, and must form the basis of all light-colored paints. Other light colors are made by adding some tinting material to them. The principal yellow color is chromate of lead, or chrome yellow. This is a very brilliant color, rather deep in shade, and the pale shades are made by adding white lead. Chrome green is a mixture of chrome yellow and Prussian blue, and is the only green pigment in common use. Prussian blue is a ferrocyanide of iron, dark blue in color. The common light blue pigment is ultramarine blue, an artificial product of complex constitution, the exact composition and preparation of which is a secret. The yellows, greens and blues are not much used in paints for structural work, but this is not the case with red pigments, the most important of which are the oxides of iron. For this purpose the sesquioxide, which is known in mineralogy as hematite, and the hydrated sesquioxide, or limonite, are used. Usually the two are mixed together in various proportions, the pigment being produced by grinding a natural oxide rock, which commonly contains from 10 to 60 per cent. of other mineral matter, commonly silicates. The color of these oxides varies from bright red to dark brown, the bright shades commonly containing most hydrated oxide and the brown (rarely dark purple) shades being chiefly anhydrous; oxides of a bright purple or maroon tint are, however, hydrated. It is commonly believed that the brown or dark red shades, that is, the anhydrous oxides, are more durable than the others. Some of these oxides are of artificial origin, such as Venetian red, which is a by-product, originally containing some sulphuric acid, to neutralize which it has been saturated with lime; and in consequence the finished pigment contains a large percentage of sulphate of lime, which cannot be regarded as a desirable ingredient. A knowledge of the chemical constituents of an oxide pigment is therefore desir-

able. A considerable proportion of silica, or of highly acid silicates, is probably not objectionable, especially if the product is nearly anhydrous; but if there is ground for believing that the silicates themselves are hydrated, they are simply clay, which is objectionable; and if any lime-salts, soluble in water or acid, are present the material is not suited for the purpose. Oxide pigments are particularly open to the criticism of being, in many cases, not finely ground, a most serious objection. Any good paint should be so fine that it feels smooth and even when rubbed on glass or porcelain with a palette knife. The importance of fine grinding is not likely to be overestimated. Ochres, umber and sienna are also classed with the iron oxide pigments, and usually contain a little manganese, which increases the drying qualities of the oil. They also contain various earthy coloring matters. The ochres are yellow in color, and the iron oxide in them is hydrated. They are often used in conjunction with white lead or zinc. Carbon, in one form or another, is the base of all the black pigments. By far the most common of these, as used in structural paints, is graphite. Other black pigments are lamp black (including carbon black) and bone black, the former being produced in many grades, varying in price from 3 or 4 cents to 60 cents per pound. Bone black, which is refuse from the sugar-house black, varies in the percentage of carbon contained, which is usually about 10 or 12 per cent., the remainder being the mineral matter originally present in the bone and containing 3 or 4 per cent. of carbonate, while most of the remainder is phosphate of lime. Lamp black is an absolutely impalpable powder which has a small amount of oily matter in it, and greatly retards the drying of the oil with which it may be mixed. For this reason it is not used by itself, but is added in small quantity to other paints, which it affects by changing their color and probably their durability. For example, it is a common practice to add it to red lead, in order to tone down its brilliant color and also to correct the tendency it has to turn white, due to the conversion of the red oxide of lead into the carbonate.

There yet remains to be described one other important pigment, —red lead. This is entitled to be placed in a class by itself, because it is intermediate between the paints which it resembles in being used mixed with oil, and the cements, which it resembles in its process of solidification. It is, in fact, a powerfully basic substance, and combines chemically with the oil, forming an insoluble, hard, tenacious mass, in which the uncombined particles of the excess of lead oxide are imprisoned. This is what constitutes the protective film when a red lead paint is dry. Red lead is said by chemists to

be a mixture of the peroxide and the protoxide of lead, the latter ingredient being the substance known as litharge. The peroxide is believed to be the characteristic ingredient. Red lead is made by a fire process in a suitably constructed furnace, and furnaces of different construction, or even of the same plan but of different dimensions, are said to give different products. At all events, it is well known that commercially pure red lead, composed of nothing but lead and oxygen, contains the peroxide in proportions ranging from 45 to 90 per cent. The correct proportions of peroxide and protoxide for making the best protective film are not known. Doubtless much of the uncertainty attaching to the use of red lead is due to this.

Linseed oil, made from flaxseed, is the liquid part of ordinary oil paints. It is sometimes obtained by treating the seed with naphtha, thus dissolving out the oil, which is separated by distilling off the solvent for use again. Comparatively little oil is made in this way, most of it being made by extraction under pressure. The seed is coarsely ground, is then heated, sometimes by running a jet of live steam into the meal, sometimes by putting the meal into a steam-heated vessel; it is then, by a machine, put into bags and pressed enough to make it take a suitable form, after which these bags are put into a powerful press and the oil is squeezed out. Moisture and other matters are of course mixed with the oil, and these are separated by allowing it to settle; it is at last filtered. This process of purification takes from one to three months, but even after this the oil improves for a long time by standing, during which some foreign matters separate and settle out. If the oil is at all cloudy at ordinary temperatures it is a sign of not being sufficiently aged. Linseed oil possesses, in a higher degree than any other oil, the property of thickening rapidly on exposure to the air. This is not due to evaporation, but the contrary; it absorbs and combines with oxygen from the air, and thus actually increases in weight, though it decreases in bulk. A paint made with raw linseed oil alone will dry so that it may be handled in five or six days, but, as this is a long time, it is thought necessary to treat the oil so that it may dry more quickly; that is, may absorb oxygen more rapidly. Oil so treated is called "boiled oil." It used to be made by heating the oil over a direct fire in a kettle, and with this oil is mixed, by constant stirring, 1 to 3 per cent. of oxide of lead, either litharge or red lead, or both, and a small proportion of oxide of manganese. When the oil reaches a temperature of about 500° F. it dissolves these metallic oxides, entering into chemical combination with them; and, as these have a great attraction for oxygen,

the resulting oil, which is much darker in color than it was, has also greatly increased drying powers, and paint made with it will dry in twenty-four hours. The dark color is due partly to the combined metallic substances and partly to heating the oil for a long time. It is believed that much more oil is present than can possibly combine with the small amount of metallic oxides, and that the product is therefore composed of a small portion of oil combined with the lead and manganese, dissolved in a large portion of oil, which is unchanged except that it has been darkened by heat. It has, therefore, become the custom of oil manufacturers to cook only a small portion of oil with the lead and manganese, and after these are dissolved they stir the product into a large quantity of raw oil at a heat about that of boiling water. The boiled oil thus made is much paler in color than that made in the old way, and is said to be quite as good in every respect. It probably is fully as good, and very likely better, being more nearly uniform. But oil made in this way varies according to the amount of oxides used, the proportionate parts of lead and manganese and the heat employed, so that boiled oil from different makers is always different, varying much more than raw oil does.

The foregoing method is the one used by the large manufacturers, but the smaller ones frequently, perhaps it may be said commonly, buy their oxides of lead and manganese already combined with just enough oil to make a compound; about four pounds of oxide of lead will combine with a gallon of oil, but the product in this case will be a solid cake. In order to liquefy this it is common to dissolve it in about two and a half gallons of turpentine or benzine (or a mixture of the two), and this solution, which is a good example of what is called a "drier," and which measures less than four gallons, contains enough metallic compound to go into about fifty gallons of oil, which is the contents of a barrel. So the small manufacturer or dealer opens a barrel of raw oil, takes out four or five gallons, fills it up with this drier, which he has purchased from some one who makes a specialty of it, closes the barrel and, after rolling it about a little to mix it, sells it for boiled oil. Such oil is said to be boiled through the bunghole, and is spoken of disrespectfully by the large manufacturers; but those who follow this practice claim that such oil is in every way equal to that made in a kettle, while it is much paler in color. It is to be observed that the turpentine or benzine employed is volatile, and to the extent to which it is used "extends" the oil. Benzine is much cheaper than oil, but turpentine is not. A still further step consists in the substitution by the makers of driers of rosin or rosin oil for linseed oil.

These are found to combine with the lead and manganese oxides even more readily than linseed oil does, and they cost only from a tenth to a fifth as much. Driers made with rosin and benzine are much less expensive than oil. The temptation is to add them in excessive quantity, and this is not uncommonly done. Such a practice is highly injurious, partly because oil thus diluted makes a thinner and less substantial film, partly because an excessive amount of driers makes the film much less durable and partly because it is generally agreed by experts that rosin is an injurious addition to oil. From a consideration of the foregoing it will appear that, while raw oil is a definite substance, boiled oil is a name applied to a large variety of manufactured products. It is also possible to make boiled oil from fish oil or other cheap oils, and these are not infrequently used to adulterate boiled linseed oil. Heavy mineral oil, such as may be purchased at one-fourth to one-half the price of linseed oil, is also used in this way. These latter practices of systematic adulteration are especially followed by the manufacturers of paints. They take the ground that the users of paint ought to pay a fair and legitimate price for linseed oil paints, and that if they prefer to purchase at a lower price it is the business of the paint manufacturer to make, at a reasonable profit, a paint which meets their requirements. It requires a tedious and expensive chemical analysis to detect these adulterations in mixed paint, and those who try to economize by buying paint below its market value are not likely to resort to such means.

The oil, variously compounded or mixed with these driers and solvents, is mixed with the finely-powdered pigment in a mixer, which is usually a cylindrical vessel provided with a revolving stirrer. The pigment has previously been ground dry to such a degree of fineness that most of it will pass through a sieve having a mesh of 100 to 200 to the linear inch. Usually it is not actually bolted, but that is about the degree of fineness which is desirable. The sharper and harder substances should be the more finely powdered. It is common to put the paint thus mixed on the market in this condition as it comes from the mixer, but the more approved practice is to take it from the mixer to a burr-stone mill and to grind the paint through the mill, thus securing a more intimate mixture and breaking up all little lumps. This grinding adds materially to the cost of the paint, and it is probably not commonly done with cheap paints intended for structural metal, since it is impracticable for an expert to take a well-mixed sample of paint and to declare, under oath, that it has not been ground.

What is meant commercially by a pure raw oil paint is made by

mixing or grinding a pigment in pure raw linseed oil to which has been added enough drier to make it dry hard enough to handle in twenty-four hours, and containing enough turpentine to amount to from 5 to 15 per cent. of the oil. This turpentine is added in order to make the paint work more freely under the brush, and also because it is the belief of the paintmaker that it is impracticable to otherwise add as much pigment to the given amount of oil as is necessary for the greatest durability of the product. It is by diluting the oil and lessening its amount in the film that turpentine acts as a drier. It does not itself promote in any great degree the oxidation of the oil, but by lessening the amount of oil it correspondingly lessens the need of metallic oxide driers. Turpentine is added for technical purposes, not for economy, and it is often more expensive than oil. On the other hand, the use of benzine is always dictated by a desire to save money. In other respects it is objectionable. Kerosene has also been very widely used as a substitute for turpentine, but does not enter into any first-class products.

Varnishes. Linseed oil is also used in the manufacture of varnishes, which are used as protective coatings, either alone or mixed with pigment. The other ingredients of varnishes are various resins, which give hardness and luster, and turpentine, which again acts as a solvent and is not in any considerable degree a part of the final permanent film, though it does oxidize somewhat, and doubtless a small part of it remains behind while the major portion evaporates. The varnish resins are of vegetable origin, having exuded, as spruce gum does, from the trunks of trees; and in some few cases these lumps of resin are detached from the living tree and sold for use. Such are called "recent" resins, and the most common one is what is called "manila," and comes from the East Indies. More often the resins are not suitable for the varnishmaker until they have acquired considerable age. The tree to which the lumps of resin are attached died and fell to the ground and decayed; the resin became gradually buried in the earth; its volatile part escaped; it became hard and brittle. In this state it is found by the natives, who dig it up and sell it to the local trader, and it becomes an article of merchandise. Such are called "fossil resins;" they are of many sorts, and are found at many places. especially in the tropics. Africa, South America and especially New Zealand are great sources of supply. These varnish resins are commercially spoken of as gums, but differ from true gums, such as gum arabic, in being insoluble in water. These pieces of resin are carefully cleaned, by scraping and otherwise, and sorted; the paler sorts are more valuable than the darker; not because they

are otherwise better, but because they are less common, and people value pale varnishes more than equally good dark ones. The varnish-maker puts a quantity of this resin, usually 100 pounds, into a flat-bottomed copper kettle capable of holding about 150 gallons which is mounted on a little iron truck, and this kettle is placed over a hot coke fire. In about half an hour the resin has melted, the temperature being from 600° to 900° F., and is found to have lost from 20 to 25 per cent. of its weight, which has gone off as a vapor. In reality, the resin has become decomposed by the intense heat, and what remains in the kettle is one of the products of this decomposition. Immediately the varnish-maker takes the kettle from the fire and adds to it some hot linseed oil, the quantity varying from about 30 pounds to sometimes as much as 300 pounds. The oil having been slowly added and well stirred in, the kettle is returned to the fire, and its contents are cooked together until combination is effected. If it is desired to produce a hard varnish, with a very brilliant surface, a comparatively small amount of oil is used; but if the varnish is to be highly elastic and durable a large proportion of oil is necessary Since one of the most essential qualities of a varnish for any ordinary use is a high degree of luster, while durability is of less account, because most varnishes wear off by use of the articles to which they are attached, it will be plain that for the preservation of structural metal work against corrosion an entirely different kind of varnish from those in ordinary use is required.

When the resinous matter and the oil are properly combined, which may take many hours, the kettle is removed from the fire and allowed to cool somewhat, and the contents are then diluted by the addition of an amount, previously found to be suitable, of spirit of turpentine, so that when cold the varnish will flow properly under the brush. Varnish is much more viscid than oil, and it is therefore possible to apply it in a thicker film. It is much harder than oil, and therefore resists abrasion; and it is much less porous than oil. It therefore naturally has by itself in some degree the qualities which we aim to give to oil by the introduction of pigments; and if it be so made and proportioned that it does not contain in itself the elements of dissociation, there can be no question that it is more valuable than an oil paint. As a matter of fact, it has for generations been used over paint to protect it from the weather, and no fact is better established than the permanence of a well-made varnish. The question naturally arises, why may we not still further increase this permanence, as we do in the case of an oil film, by the addition of a pigment? If the latter works so well with

oil, why may it not with varnish? The fact is that pigments do increase the durability of varnishes for the same reasons and in the same degree that they benefit oil films, and by far the most permanent paints which it is possible to make are made in this way. These will not, of course, be as brilliant and lustrous as the varnishes alone, the pigment having an opposite effect, but will be far more so than an oil paint, and will be smoother and harder; while if properly made, they will remain sufficiently elastic. Varnishes are sometimes observed to crack and to come off bodily, instead of wearing off from the surface. This is the worst fault a varnish can have, and is due to its being made of unsuitable materials or in an unskillful way. Any considerable amount of common rosin in a varnish will cause this, and it may also be due to other causes. A good varnish, used for the purpose for which it was designed, will not do it. The commonest adulterant of varnish is rosin, which may itself be made into a varnish and mixed in any proportion. A well-made rosin varnish has a very brilliant surface, and works fairly well under the brush, but a comparatively small amount of rosin will simply destroy the durability of the best varnish.

The objection to the use of varnish paints is their cost. From the nature of things, varnish is much more expensive than oil. When one puts so valuable a material as a good varnish into a paint he naturally will insist on putting it through a mill, and when we compare the cost of it with that of an oil paint run through a mixer there will be a striking difference. Suppose it costs twice as much. This would probably be a minimum. The minimum cost of applying any paint will be as much as the price of the oil paint. Then, when the two are applied, they have cost in the proportion of two to three. If the varnish paint will last fifty per cent. longer than the oil paint, it will then be as economical. It is the opinion of the writer that it has been proved by actual use to be more than 100, and in many cases 300, per cent. more lasting.

Varnishes are also made which contain asphaltum, which is a mineral resin, instead of the vegetable resins already described. These are, of course, black, and they may be made with part vegetable resins and part asphaltum if so desired. The objection to asphaltum is that when used with any considerable proportion of linseed oil its remarkable non-drying qualities make it difficult of use. Its advantage is its cheapness and also its wonderful permanence. When properly combined, however, it is a most valuable material. The simplest way to overcome its effect of preventing the oxidation of oil is to subject the varnished object to the action of hot air. The activity of the oxygen is thus enormously in-

creased, and oxidation proceeds in spite of all obstacles. This is the process known as japanning or enameling, and it has the further advantage that the adhesion of the coating to the metal is much increased, while at the same time the porosity of the coating is reduced almost to nothing. This is because the coating material is kept in a melted or semi-fluid condition while the oxidation is going on, and the pores are destroyed or closed by the flowing of the material itself.

The way this is done is by coating the object, usually by dipping it in the varnish. Then it is put in an oven and baked at a temperature of from 200° to 400° F. for several hours. Sometimes several coats are thus applied in succession. Varnish paints are sometimes applied in this way, making colored enamels of great beauty and durability. But it is possible to use asphaltum in varnishes which will dry at ordinary temperatures. This is most commonly done by using very little oil; also by a large amount of driers, but better by mixing a varnish of asphaltum with one made of other resins. It is also possible to make a varnish containing a considerable amount of asphaltum which will dry reasonably well by great care and skill in its fabrication. It may safely be said that asphaltum is one of the most difficult substances to use, and that while excellent results are obtainable, they are more difficult to obtain than with any other substance, and that bad results are very common.

In conclusion, it remains to be observed that while nothing is here said of the importance of methods to be employed in cleaning the metallic surface, this is not because it is a matter of minor importance. On the contrary, it is of so great importance that a separate discussion of its value and the means of doing it would be necessary, and this paper is therefore confined to an account of the materials used. The comparative value of these is difficult to determine, and varies in different cases; but in general the writer has been led to the conclusion that there is not a very decided difference between different pigments in their value for the prevention of corrosion; that varnishes and varnish paints, when made with proper knowledge and skill, are better than oil paints; that these latter give probably better average results than red lead, but that, when the best possible results of red lead are attained, it is considerably better for most exposures than oil paints, and that the use of adulterated materials, either through ignorance or design, is a most serious and common evil. This is rather the fault of the purchaser than of the maker. If the former would not buy, the latter would not make the inferor article. It is within my knowl-

edge that, at the time of writing this, steel frame buildings costing over a million dollars are being erected on which red lead paint is specified; the paint to contain 15 pounds of red lead to the gallon, the cost of materials at wholesale being about $1.30. The paint actually used, and guaranteed to pass the inspection, costs the painter 60 cents per gallon. This is not an exceptional case; such things are going on constantly. The purchaser or his agent is to blame, and it is a valid criticism of very many engineers that they are willing to let contracts at prices which, if the undertaking were properly carried out, would entail loss to the contractor. It does not pay to do business with a man who is losing money. The contractors are the men who build these great engineering structures. The engineers do not build them, nor do the capitalists, but it is the men who do the actual work and who make the necessary parts and supplies; and they are entitled to fair pay for their labor and skill and materials supplied; and when they are told that they will not be paid for a good article, they will be likely to supply an inferior one. Since the range of prices, in the case of paints for structural work, is about 400 per cent., it is natural that inferior articles should be often substituted for better ones in this line if they are in any.

THE ENGINEERS' CLUB OF ST. LOUIS; ITS HISTORY AND WORK.*

By William H. Bryan, Member Engineers' Club of St. Louis.†

Shortly after the close of the Civil War, when a number of engineers, returning from army duties, had settled in St. Louis, there was a feeling that something should be done in the direction of associated professional effort. This feeling resulted in the organization, on December 22, 1865, of the "Polytechnischer Verein," with Colonel Henry Flad as President and Geo. P. Herthel, Jr., as Secretary, both of whom served the Engineers' Club of St. Louis, when organized four years later, in similar capacities. The "Verein" was open to all scientific and technical men, and its discussions and the records of its proceedings were in German. A member absenting himself from a meeting was fined 25 cents. If he was present at roll call and then left the fine was 50 cents. A Chairman was chosen at each meeting, but the Secretary and Treasurer were elected for six-month periods, which practice was also followed at first by the Engineers' Club. The articles of association provided that should the "Verein" disband its library was to be turned over to the O'Fallon Polytechnic Institute. Among the subjects discussed were cements, strength of material, nitro-glycerine, bridges and electricity.

Its meetings were not always harmonious, for we find that at the eighth meeting a lively discussion took place between Colonel Flad and Secretary Herthel over a newspaper article written by the latter. Colonel Flad left the meeting, and Mr. Herthel was requested to leave, later sending in his resignation. At the tenth meeting, however, both are reinstated, and everything is lovely. I have been unable to learn how long this society continued in existence. The records I found covered a period of but six months.

Later it seems that the engineers concluded to "flock by themselves," and we hear of informal gatherings, these being held—let it be told in whispers—in the back room of a saloon on Seventh street and Chouteau avenue. Among those frequenting these informal meetings were Messrs. Flad, Herthel, Whitman, Davis, Rice, Meysenburg and Lowe. These meetings led to the formation of the Engineers' Club of St. Louis, the first meeting of which was held on November 4, 1868, at the office of the Water Board, at the

*An address delivered at a meeting held April 19, 1899, at the Southern Hotel, in celebration of the 30th anniversary of the Club's incorporation.

†Manuscript received February 26, 1900.—Secretary, Ass'n of Eng. Socs.

southeast corner of Fourth and Elm streets. I quote the minutes of this meeting in full:

At a meeting of engineers held this day at the office of the Water Board, Mr. Whitman was elected Chairman and Mr. Eimbeck temporary Secretary.

Upon motion, resolved that an association be formed to be styled the "Engineers' Club," for the general advancement of professional knowledge, intercourse and for maintenance of a library of journals and books of reference.

Upon motion, resolved that any engineer may attain membership of this Club by signifying his desire to enter and by assuming the obligations to contribute to the fund necessary for the maintenance of the library, similarly to old members.

Resolved further that the officers of the Club be a Secretary and Treasurer, having the duties as ordinarily defined. George P. Herthel, Jr., was elected Secretary, and Joseph P. Davis, Treasurer.

Upon motion, the Chair appointed the Secretary and Treasurer a committee to receive and nominate to each meeting topics of professional interest for discussion.

Upon motion, the Chair appointed Messrs. Merrill, Flad and Davis a committee to report on such a list of periodicals as might be desirable.

Thereupon discussions by the Club on general topics. Topics submitted for the next meeting by Col. Flad, "Pile Drivers"; Col. Merrill, "Dykes."

Adjourned.

At the second meeting an assessment of $10 was levied for library purposes, and a list of periodicals ordered. At the third meeting a Committee on Constitution was appointed, which committee made its report at the fourth meeting, and the Constitution was adopted. At the fifth meeting the Constitution was reviewed, and received the signatures of fifteen members. At this meeting the first annual election of officers occurred, the result being: Colonel Henry Flad, President; F. E. Shickle, Vice-President; Geo. P. Herthel, Jr., Secretary, and Jos. P. Davis, Treasurer.

The proper office of the Club seems to have had early consideration, for at the thirteenth meeting a Dr. Hunter introduced and explained his model of a canal boat propeller, and a motion was carried that the Club give same its unqualified approval. This appeared to have been a little strong, for the motion was reconsidered at the next meeting and referred to a committee of three. At the following meeting Dr. Hunter was present and gave additional data. Several meetings later a resolution was adopted declaring it to be inexpedient for the Club to engage in controversies about the merits of inventions, and an amendment to the By-laws was adopted to the effect that no vote should be taken or record made of such debates. This, it is needless to add, has been the policy of the Club ever since.

At the twenty-third meeting, held April 2, 1869, a committee was appointed to investigate the matter of incorporating the Club. This committee reported favorably at the following meeting, and a committee was appointed to proceed with the matter. At the twenty-ninth meeting, held May 19, 1869, this committee presented the certificate of incorporation, dated May 12, 1869. From this it appears that for some time the Club has been badly mixed as to its dates. As far back as I can remember the date of incorporation has always been published as April 12. This meeting, therefore, is nearly a month too early, not to mention the fact that we seem to have forgotten that the Club was organized some six months before it was incorporated.

INCORPORATORS AND CHARTER MEMBERS.

The men whose names appear as incorporators of the Engineers' Club of St. Louis are: Messrs. Henry Flad, Geo. W. Fisher, Thos. J. Whitman, L. Frederick Rice, T. A. Meysenburg, William Eimbeck, Chas. Pfeifer, C. E. Illsley, Geo. P. Herthel, Jr., Jos. P. Davis and Jas. Andrews. A careful inspection of the records, however, shows that this list does not include the entire membership of the Club at that time, and that a number of names—some of them active and prominent in the Club—are missing.

No name deserves so high a position in the annals of this Club as does that of Colonel Henry Flad, its first President, and for twelve years, 1868-1880, the occupant of the chair. At the meeting held September 21, 1898, in honor of Colonel Flad, a complete biographical sketch of his life was given by Mr. Robert Moore, so that it is not necessary to recapitulate here. He did some notable work in the Civil War, was actively connected with the St. Louis Bridge, and was really the brains behind that structure. His connection with municipal work in St. Louis is well known, and to him is due the credit in large measure for our water works system, paved streets and system of street sprinkling. He served a term as President of the American Society of Civil Engineers, and was a member of the Mississippi River Commission, rendering important service there, particularly in the matter of dredging. His death occurred June 20, 1898. His son Edward has been active in the Club for many years, serving as President in 1897.

Geo. W. Fisher was very active in the Club in its early days, holding the office of Vice-President during the years 1874-77, inclusive, and being still a member of the Club. During nearly all of this time he has been connected with the Fulton Iron Works, of this city, of which he is now the head.

Thos. J. Whitman served the Club as Treasurer for part of 1870, as Vice-President during 1878-80, and as President during 1881. He was actively connected with the St. Louis Water Works system, and was for many years the head of the Water Department. He also did important work in connection with the water plants at Memphis and Leavenworth, and the sewer system at Minneapolis. His death occurred in December, 1890.

L. Frederick Rice was Secretary of the Club in 1871, during which year he removed from the city. For some years past he has practiced his profession of architecture and civil engineering in Boston. He writes that he still cherishes the recollection of those old days, and of the pleasant acquaintances made during his residence in St. Louis.

Colonel T. A. Meysenburg was a charter member of the "Polytechnischer Verein" as well as of this Club, and is still on our rolls. He delivered the formal address on the occasion of the celebration of the Club's twentieth anniversary. For many years he has been connected with extensive iron and steel manufacturing interests in East St. Louis.

William Eimbeck was also quite active in the Club in its early days, but for many years past has been connected with the United States Coast and Geodetic Survey. He expected to be with us this evening.

Charles Pfeifer was intimately associated with Captain Eads and Colonel Flad in the design and construction of the bridge, and did much of the intricate technical work connected therewith. For a time the firm of Flad & Pfeifer did independent work as consulting engineers, with offices in the old Chouteau residence on Sixth and Olive streets, where Barr's now stands. Mr. Pfeifer was later connected with one of the city departments, and died in February, 1883. His son, H. J. Pfeifer, is now a member of the Club.

Chas. E. Illsley was at one time active in the Club and in engineering work, but changed his vocation to that of architecture, and recently removed to Boston.

Geo. P. Herthel, Jr., was one of the most active spirits in the early work of the Club, being intimately associated with Captain Eads and Colonel Flad. Born in 1841 in this city, he was graduated from the Rensselaer Polytechnic Institute, studying also in the Berlin and Carlsruhe Polytechnic Schools. He assisted Captain Eads in the design of his gunboats, organized a patent agency and in 1866 served the city as gas inspector. He was also connected with the water works. In co-operation with Colonel Flad he designed and erected the first hydraulic elevators put up in this city,

these being located on Main and Market streets, in Mr. Chouteau's buildings. In 1867 he made a survey of all the bridges on the Mississippi and Missouri Rivers for the Government under General Warren. He was a specialist in bridge work, and patented a parabolic truss bridge of which a cast iron hollow column formed the top chord, over forty of which were built. He was very active in the early discussions of the St. Louis Bridge enterprise as an advocate of the Eads design. He died October 24, 1870. For these data and other facts of interest I am indebted to his brother, Mr. John W. Herthel, architect, of this city, who, with his daughter, is with us this evening.

Jos. P. Davis was the first Treasurer of the Club, serving it during the years 1868-69 and part of 1870. He left St. Louis in 1870, and has been connected with the Bell Telephone Company, of New York, for some years. He writes me that the Club's property then consisted of a small blackboard and a large table, in the engineer's office of the Water Board, around which the members sat. Colonel Flad, he says, was oftener at the board than any other member, and made the meetings interesting by stating the new problems and their solutions which he met in the development of the plans for the bridge.

Captain Jas. Andrews was intimately associated with Captain Eads on his bridge and jetty enterprises, and for many years made his home in Pittsburg, where he was identified with many important interests. His last work in St. Louis was in 1894, when he was associated with Mr. Robert Moore as United States commissioners in placing a valuation upon the Kansas City Water Works plant. He died July 6, 1897.

Among early members whose names do not appear in the incorporation papers was Frederick E. Shickle, who was the Club's first Vice-President, serving it in that capacity from 1869 to 1873, inclusive. He was actively connected with the Shickle, Harrison & Howard Iron Company, of this city, until his death, in March, 1888.

Another early member is Wm. Wise, who is still with us, and who is, in fact, the only one of the Club's charter members who now rarely misses a meeting. The Club is under many obligations to Mr. Wise, for he served it as Treasurer for ten years, 1871-80, inclusive, and was its Vice-President in 1882. During all this period he has been connected with the Sewer Department of the city, and took an active part in the construction of the Mill Creek sewer.

Another early member was Colonel W. E. Merrill, then chief engineer of staff for General W. T. Sherman, and who was at work

on topographical maps for the Government. He left St. Louis in 1870, and after a year in Chicago went to Cincinnati, where he had charge of the improvements on the Ohio River. He built the Davis Island movable dam, the first of this type on a large stream, which resulted in giving Pittsburg a deep water harbor the entire year. His death occurred on December 14, 1891.

THE EX-PRESIDENTS.

We begin again with Colonel Flad, our first President, and who served from 1868 to 1880. His election to honorary membership occurred January 16, 1895.

As already stated, Thos. J. Whitman was our second President, serving the Club in 1881.

General C. Shaler Smith, 1882, was a prominent bridge engineer, designing the St. Charles and LaChine Bridges and many other prominent structures. I am told that his election to office in this Club, which occurred immediately after the falling of the St. Charles Bridge, and at a time when he was being severely censured, was largely due to the opinion among engineers that General Smith's designs were in accordance with the best practice of the day, and was intended to show that he had in no wise lost the confidence of his professional brethren. For a number of years he was in charge of the Eads Bridge. He died December 20, 1886.

Colonel H. C. Moore, 1883, was a prominent railroad man, having been general superintendent of the Missouri Pacific and other important Western roads. His sons, Robert and Philip N. Moore, have for many years been active members of this Club. His death occurred in April, 1889.

Dr. C. M. Woodward, 1884, has for many years been prominent in the education of engineers, which, together with his book on the St. Louis Bridge, entitles him to high rank as an engineer. The records indicate that this Club is largely indebted to Dr. Woodward for its present standing and prosperity. In 1883 interest in Club affairs was at a low ebb, no meetings being held between April and December. At the December meeting Messrs. Woodward, Constable and Robert Moore were appointed a committee to arrange a scheme of work for the coming season. At the following meeting, January 2, 1884, they reported a program which embodied meetings on the first and third Wednesdays of each month, and one or two papers for each meeting. The committee had adopted heroic measures; had selected interesting subjects, and secured the consent of persons familiar with those subjects to talk upon them. The committee regretted its inability to find one who could properly

discuss electric motors. The Club was so pleased with the plan proposed that it immediately elected Dr. Woodward President. This arrangement of two meetings per month and a definite program has been followed ever since, and is largely responsible for the growth and prosperity of the Club. As will be shown later, there was an immediate revival of interest, which has continued ever since.

Robert Moore, President in 1885 and 1893, has, as you know, been identified with many prominent engineering works, principally in railways, water and other municipal enterprises. He is an eminent example of the engineer as a citizen. His public work in smoke abatement, water filtration and in the public schools and library are well known. Perhaps his most important structure is the elevated railway in this city.

Robert E. McMath, President in 1886 and Librarian 1891-93, is well known to the public as former Sewer Commissioner and now President of the Board of Public Improvements. His latest public service, and by no means the least important, is his connection with the recent exposure of the engineering fallacies of the Chicago Drainage Canal.

Professor W. B. Potter, 1887, is well known through his work at Washington University and in mining and metallurgy. His studies of Western fuels and the abatement of smoke have earned him high standing. He served a term as President of American Institute of Mining Engineers.

M. L. Holman, 1888, and Treasurer in 1885 and 1886, has been almost continuously connected with the Water Department of this city, of which he has risen to the head, and where he has done much work in extensions and enlargement of water works system. No engineer in public life to-day enjoys the confidence of his professional associates and the public generally to a greater degree than does Mr. Holman. He served several terms as one of the Vice-Presidents of the American Society of Mechanical Engineers.

Colonel E. D. Meier, 1889, Treasurer 1881-84, has had a wide experience as a mechanical engineer in railway work, cotton, coke and boiler manufacturing. The Colonel is a very agreeable gentleman, but, like some of the rest of us, has his hobbies. One of these, the largest Heine boiler yet built (600 horse power at 300 pounds working steam pressure), has just been put into service at the Baldwin Locomotive Works, Philadelphia, within forty-eight hours after the old boiler plant had been shut down. Another hobby of the Colonel's is the Diesel motor, of which great things are expected. Colonel Meier is now one of the Vice-Presidents of the American

Society of Mechanical Engineers. He was for many years Secretary of the American Boiler Manufacturers' Association.

Professor F. E. Nipher, 1890, was Vice-President in 1889, and is now. He is well known through his educational work at Washington University, and his original investigations into electrical and physical science, and his publications on those subjects.

George Burnet, 1891, served as Street Commissioner and as President of the Board of Public Improvements, and is well known as a cable and railway contractor.

Professor J. B. Johnson, 1892, Secretary 1883-84, Librarian 1885-88 and 1890-91, stands high as an educator in civil engineering, having recently accepted the position of dean of the School of Engineering of the University of Wisconsin. His several textbooks on important engineering subjects, and his more recent investigations into the strength of materials, have earned for him high rank, and it is a source of extreme regret that he should leave Washington University and St. Louis.

Robert Moore served another term as President in 1893. This, you will remember, was the year of the Chicago World's Fair, and it was thought that this Club would have something to do in the direction of entertaining visiting engineers from abroad, and it was felt that the Club should have at its head at this time one of our best known and most representative engineers. This honor, of re-election to the Presidency after a term of years, has been conferred by the Club on no other member.

B. L. Crosby, 1894, was prominently identified with the Burlington Railway, and has had charge of the construction of many important bridges across the Missouri River. He also served the Club as Vice-President during the years 1892-93, removing to St. Joseph, Mo., about a year ago.

S. Bent Russell, 1895, has been almost continuously with the Water Department of this city, and for many years has been in direct charge of the extensions. The Club is principally indebted to him for its publication of "Local Data." His most recent work is the revetment of the banks of the Mississippi River at the Chain of Rocks.

J. A. Ockerson, 1896, served as Vice-President in 1888 and 1895. He was for many years principal assistant engineer to the Mississippi River Commission, and last summer was appointed to succeed Colonel Henry Flad as a member of the commission. He has been identified with much important work on the Mississippi and its passes.

Edward Flad, 1897, was prominently connected with the Water Department for a while, but for many years has been engaged in

independent practice, in which he was associated for a time with Professor J. B. Johnson. A piece of characteristic and original work is his design of standpipe for the St. Charles, Mo., water works.

Personally the speaker would have preferred to draw the line on ex-Presidents at this point, but historical accuracy forbids. William H. Bryan, President in 1898, has been much in evidence in the Club's affairs for a number of years, serving as Secretary from 1886 to 1890 and from 1894 to 1896, and as Librarian in 1889, and is at present a member of the Board of Managers of the Association of Engineering Societies. His work as an engineer is known to many of you, his efforts in the direction of smoke abatement being perhaps those in which he feels the most satisfaction. In his recent design of the Imperial Electric Light, Heat and Power Company's plant at Tenth and St. Charles streets, in this city, he was associated with Mr. H. H. Humphrey.

I regret to state that I was unable to secure the consent of the present occupant of the chair to the use of his photograph. I would have liked very much to present it with those of the ex-Presidents, for several reasons: First, Mr. Colby is a prominent and able engineer whom we all delight to honor, and, second, there is every indication that in the course of time—if the Club is true to its traditions—he may hope to become an ex-President. Not being able to get his consent, however, I was obliged to forego that pleasure and resort to other methods. You are familiar with Mr. Colby's long connection with the Sewer Department, of which he is now the head, and the important work which he has done in repairing the Mill Creek sewer.

OTHER PROMINENT ENGINEERS.

Professor Chas. A. Smith was Secretary of the Club from 1872 to 1882, inclusive. To him we are largely indebted for our present methods of publication and the establishment of the Journal. His work at Washington University as professor of civil and mechanical engineering is well known. This Club numbers many of his students on its rolls, five of them being ex-Presidents. His two books, "Steam Making" and "Steam Using," have long been authorities in their fields. His death occurred on February 2, 1884. In recognition of his services a purse of several hundred dollars was made up in 1890 and presented to Professor Smith's son.

Captain Jas. B. Eads was another prominent member whose work in connection with the bridge, jetties and gunboats is well known. He served a term as president of the American Society of

Civil Engineers in 1880, and died March 8, 1887. The Club has a standing committee on monument to Captain Eads, and a considerable fund has been raised; not enough, however, to enable the work to be begun.

William E. Worthen was elected an honorary member of this Club October 30, 1872, and for twenty-three years was the only honorary member. He was an ex-President of the American Society of Civil Engineers, and for a short period was chief engineer of the Chicago Drainage Canal. He died April 2, 1897.

A number of the Club's members entered the Third United States Volunteer Regiment of Engineers when it was formed in this city in the summer of 1898. Among them were Colonel E. J. Spencer, Major J. L. Van Ornum, Captain J. A. Laird, Lieutenant W. S. Brown and Messrs. L. P. Butler, S. F. Crecelius and H. L. Reber.

AN ABSTRACT OF THE CLUB'S HISTORY.

The accompanying table, page 168, gives an abstract of the Club's history. It will be noticed that the President and Vice-President have, since 1880, been changed each year, the Vice-President as a rule becoming President. The records are silent as to who was Vice-President in 1883. The Secretaries have been Messrs. Herthel, Rice, Professors Smith and Johnson, Messrs. Miller, Bryan, Thatcher, McCulloch and Fish. The Treasurers Messrs. Davis, Whitman, Wise, Meier, Holman, Melcher and McMath. The office of Librarian, which was established in 1885, has been filled by Messrs. Johnson, Bryan, McMath, Condron, Judson, Layman, Baier and Jolley.

For about a year and a half after the Club's organization meetings were held regularly once a week, and there are records of fifty-two separate and distinct meetings in the year 1869. The attempt was made to keep up the weekly meetings, but with only indifferent success. In February, 1874, a motion was adopted providing for meetings on the first Wednesday of each month, but even this was found difficult to maintain. Some of the early meetings were not particularly thrilling in interest. For instance, the minutes of the thirty-fifth meeting read: "Meeting called to order by Mr. Rice. Upon motion, Mr. Whitman elected as temporary Chairman. On motion, adjourned."

During the years 1869 to 1873 much important engineering work was in progress in this city, including the bridge, the tunnel and Bissell's Point water works. After these were finished interest in the Club seemed to lag; so much so that but two meetings were held in 1875, and one of these was the adjourned annual meeting

ENGINEERS' CLUB OF ST. LOUIS.

Year.	Meetings. Years.	Meetings. Total.	PRESIDENT.	VICE-PRESIDENT.	SECRETARY.	TREASURER.	LIBRARIAN.	Members.	Aver. Attendance.
1868	9	9			G. P. Herthel, Jr.	J. P. Davis.			
1869	52	61	Henry Flad.	F. E. Shickle.	" "	" "			
1870	36	97	" "	" "	" "	T. J. Whitman.			
1871	28	125	" "	" "	L. F. Rice.	William Wise.			
1872	21	146	" "	" "	C. A. Smith.	" "			
1873	13	159	" "	" "	" "	" "			
1874	8	167	" "	G. W. Fisher.	" "	" "			
1875	2	169	" "	" "	" "	" "			
1876	3	172	" "	" "	" "	" "			
1877	4	176	" "	" "	" "	" "			
1878	11	187	" "	T. J. Whitman.	" "	" "			
1879	5	192	" "	" "	" "	" "			
1880	11	203	" "	" "	" "	" "			
1881	8	211	T. J. Whitman.	C. S. Smith.	" "	E. D. Meier.			
1882	5	216	C. S. Smith.	William Wise.	" "	" "			
1883	4	220	H. C. Moore.		J. B. Johnson.	" "			12
1884	18	238	C. M. Woodward.	Robert Moore.	" "	" "		126	23
1885	17	255	Robert Moore.	R. E. McMath.	T. D. Miller.	M. L. Holman.	J. B. Johnson.	120	25
1886	14	269	R. E. McMath.	W. B. Potter.	" "	" "	" "	120	19
1887	14	283	W. B. Potter.	M. L Holman.	W. H. Bryan.	C. W. Melcher.	" "	133	21
1888	15	298	M. L. Holman.	J. A. Ockerson. E. D. Meier.	" "	" "	" "	150	28
1889	18	316	E. D. Meier.	F. E. Nipher.	" "	" "	W. H. Bryan.	164	30
1890	22	338	F. E. Nipher.	Geo. Burnet.	" "	" "	J. B. Johnson.	179	30
1891	18	356	Geo. Burnet.	N W. Eayrs. J. B. Johnson.	A. Thacher.	" "	" " R. E. McMath.	177	28
1892	18	374	J. B. Johnson.	B. L. Crosby.	" "	" "	" "	186	29
1893	16	390	Robert Moore.	" "	" "	" "	" "	180	26
1894	18	408	B. L. Crosby.	S. B. Russell.	W. H. Bryan.	T. B. McMath.	T. L. Condron.	179	30
1895	19	427	S. B. Russell.	J. A. Ockerson.	" "	" "	J. N. Judson. W. A. Layman.	181	22
1896	18	445	J. A. Ockerson.	Edward Flad.	" "	" "	" "	182	23½
1897	18	463	Edward Flad.	W. H. Bryan.	R. McCulloch.	" "	Julius Baier.	186	27½
1898	18	481	W. H. Bryan.	B. H. Colby.	" "	" "	E. J. Jolly.	201	29½
1899	18	499	B. H. Colby.	F. E. Nipher.	E. R. Fish.	" "	" "	202	36
1900			W. S. CHAPLIN.	E. J SPENCER.	F. E. BAUSCH.	E. R FISH.	J. L. VAN ORNUM.		

from the year before. The table is in error regarding the meetings held in 1876. Seven were actually held, but for some reason four of them did not receive numbers. Our total of numbered meetings is therefore four short of the actual number. The columns showing total membership and average attendance at meetings are interesting. I could not find these data in the records of the earlier meetings, but it is evident that a marked increase in the number of meetings, average attendance and total membership began with the adoption of a set program of papers in 1884, as has already been explained.

The next period of seven years was an active one for the Club, its membership increasing over 70 per cent. and the average attendance doubling. The growth in the five following years did not seem to continue, but there has been a revival in the last year or two. For the last fifteen years the program of two meetings per month, except during the hot weather, has been maintained.

PAPERS AND PUBLICATIONS.

During its existence the Club has discussed a wide variety of subjects. At the early meetings some of the topics covered were pile driving, dykes, foundations, the Hoosac tunnel, pontoons, street rollers, boiler explosions, pavements, steamboat engines, railroad grades, siphons, injectors, cement, fire clay, iron manufacturing, borings in deep water, pumping engines, standpipes, suspension bridges, draw bridges, electric clocks, the Biddle street sewer and improving the Meramec River.

The first formal paper was presented by Mr. J. C. Davis, and was entitled "Screw Piles," and the minutes state that it was "added to the records." Afterwards when a paper of unusual value was read it was, by special vote, ordered to be published in pamphlet form at the Club's expense. There is a record also of the Secretary buying a book into which to copy papers. The records also show that at one time (1876) the Club's proceedings were reported quite fully in the *Engineering News* for some months. At another time, 1884, one of the morning papers printed the minutes in full for a while. In 1881 the Association of Engineering Societies was formed, and the publication of the JOURNAL begun. This journal has not always been as successful and prompt as it now is. For instance, the minutes of the Club's meeting of January 16, 1884, are published in the JOURNAL for July, 1883.

There were also occasional publications of the Constitution and By-laws and list of members. Beginning in 1889, this became an annual feature, and in 1896 was enlarged to the present bulletin;

and now includes the annual reports of officers and the addresses at the annual dinner and other matters of interest, and is more than self-supporting from advertisements secured. Not the least valuable of the Club's publications is the pamphlet on "Local Data," issued in 1893. We have a large number of copies on hand, and it has been suggested that it be revised and republished in the next annual bulletin.

LIBRARY AND MEETING PLACES.

The Club has made various attempts towards the formation of a library. One of the first things it did was to subscribe for technical journals, which were afterwards bound. Numerous donations of books were received. Arrangements were made to copy into the Club's records the results of the experiments during the construction of the St. Louis Bridge. When the contract was made with the Public School Library in 1872 all the Club's books were turned over to it, and we were never able to get them back. Efforts towards the formation of a library were resumed when we secured quarters of our own in the Laclede Building in 1889, and have continued uninterruptedly to the present time, when we have a library that is beginning to be worthy of the Club. In 1891 the Club secured a most valuable acquisition to its possessions by purchasing the library of the late Mr. Thos. J. Whitman, the necessary funds being raised by subscription. In 1895 an arrangement was made with the Electric Club by which the latter's valuable library is cared for by the Engineers' Club, and open to use by its members.

Among the Club's possessions are also a number of valuable portraits,—oil paintings of Captain Eads and Colonel Flad, and crayons of General C. Shaler Smith, Thos. J. Whitman and Professor Chas. A. Smith.

The Club's meetings for the first three years of its existence were held in the office of the Water Commissioner, southeast corner Fourth and Elm streets. Under the arrangement with the Public School Library, which was in force from 1872 to 1881, every member of the Club became a life member of the public library, and at a cost of $12, and the two libraries were merged into one, and we were given a meeting room. This arrangement was never entirely satisfactory, for we find that in 1876 meetings were being held at various other places,—at the office of the St. Louis Bolt and Iron Company, Flad and Pfeifer, Washington University and the Board of Public Improvements. After 1877 the meetings were again held at the public library until 1881, when the Club withdrew from the agreement. From 1881 to 1884 the meeting place was the office of the Board of Public Improvements, then on the ground floor of the

old City Hall, at Eleventh and Market streets, in the room until recently occupied by Water Commissioner Holman. In 1884 arrangements were made with the Mercantile Library by which the Club took forty annual memberships, and were given a meeting place. This arrangement continued until 1887. For a year of this time, however, meetings were held in the rooms of the old Mercantile Club by special invitation, and without expense. During the next two years meetings were held usually at Washington University, but in the spring of 1889 arrangements were made with the Elk's Club in the Laclede Building for a meeting place, and a special room was rented for the Club's use as a library on the third floor of the same building. This arrangement proved quite satisfactory, and continued until the end of 1890, when a larger room was rented in the Odd Fellows Building, which served for both library and meeting room. This arrangement continued until December, 1893, when the present contract with the Missouri Historical Society was entered into, and has proved eminently satisfactory ever since.

DINNERS AND ENTERTAINMENTS.

The first dinner of which I find any record was held at the St. Louis Club December 1, 1880, the annual meeting. Another dinner was held a year later at the same place. The third was planned to be held at the Germania Club at the annual meeting of 1882, but a blizzard struck the town that evening and no quorum appeared. The records state that those present "took what refreshments they could" and adjourned. No further dinners appear to have been held until March, 1886, when a complimentary banquet was tendered Colonel Flad at Faust's Cabin in honor of his election to the Presidency of the American Society of Civil Engineers. On April 11, 1888, a dinner was tendered Professor W. B. Potter at the University Club, in honor of his election to the Presidency of the American Institute of Mining Engineers. The twentieth anniversary of the organization of the Club was celebrated by a dinner November 7, 1888, at the Lindell. A complimentary dinner was given T. C. Mendenhall, superintendent of the United States Coast and Geodetic Survey January 18, 1890, at the University Club. On May 12 of the same year the Club celebrated the twenty-first anniversary of its incorporation by a dinner at the Elk's Club. They seem to have gotten the date right this time. A dinner was held at the annual meeting December 2, 1891, at the Mercantile Club. After this the practice was begun of holding the annual dinner at the last meeting of the year, when the newly-elected officers were installed, which custom has continued up to the present time, the dinners of 1892, 1893, 1894, 1895 and 1898 being held at

the Mercantile Club and those of 1896 and 1897 at the Southern Hotel.

President Edward Flad in 1897 appointed a Reception Committee to look after entertainments, excursions, visitors, etc., and his successors in that office have appointed a new committee the beginning of each year. This has proved an excellent feature. President Flad also began the practice of serving a light lunch at the close of each regular meeting, which practice has been followed more or less regularly ever since. During 1898 the custom was begun of having annually one or more meetings of a popular character, and inviting the ladies to attend.

EXCURSIONS.

A not unimportant feature of the Club's work has been excursions to engineering structures in progress of erection or completed in this vicinity. This began at an early day; trips were made to the St. Charles Bridge on April 16, 1869, and June 25, 1870. Frequent visits were made to the Eads Bridge and to the water works. Trips were also made to Pilot Knob and the East St. Louis Coke Works, and to the Chanute Bridge, Kansas City. An excursion was made to Crystal City May 31, 1884. The Merchants Bridge and Elevated Railways were visited April 25, 1891, and the water works and Burlington Bridge on June 15, 1895.

Among the more recent excursions may be mentioned the inspection of the dredge boats July 18, 1897, and the visit to Grafton August 25, 1897, to Granite City May 28, 1898, and to the Osage River October 16, 1898.

Other interesting matters shown by the records are the contribution of drawings and photographs to the Paris Exposition in 1878, the entertainment of the Master Mechanics Convention in 1877, the entertainment of the Civil Engineers in 1880 and of the Mechanical Engineers in 1896. The latter meeting led to the establishment of the Club's fund for the entertaining of visiting engineers, which now amounts to nearly $1000.

MISCELLANEOUS.

The minutes of the Club are not as dry reading as might be supposed. At the early meetings seven members formed a quorum, and it frequently happened that this number was not present. Shortly after the agitation of Dr. Hunter's paper on "Paddle Propellers," Mr. Pfeifer submitted a problem in arched trusses and offered a premium of $5.00 for its solution. This was, however, without result, and the offer was withdrawn two meetings later,

only to be followed by a solution from Mr. Herthel at the next meeting. At the thirty-second meeting a committee was appointed to bring in absentees, which committee retired, located the delinquents and brought them in, and were, on motion, relieved from further duty. The record is silent as to where the absentees were found.

Great interest was taken in the improvement of navigation in the Mississippi River. At the sixty-first meeting four committees were appointed to consider this subject, each consisting of three members, but I can find no record that any of them ever reported.

The closing clause of the minutes of the sixty-fourth meeting reads: "After which there was a general fight on the law of the strength of columns," which might be said with equal truth of many meetings since that early day, some of them quite recent.

The records of the one hundred and fourth meeting mention that a discussion took place upon the recent tornado in East St. Louis, in which various members of the Club joined. What happened to them after they joined the tornado is not stated.

At the one hundred and fourteenth meeting a scheme is mentioned for supplying Belcher water to the central portion of the city, by which the weight of the drinkers was to raise the water.

As late as the two hundred and thirty-fourth meeting the President, in calling the meeting to order, stated that its object was to keep the JOURNAL supplied with copy.

The question of smoke prevention has been before the Club since a very early day. At a meeting of March 4, 1876, Messrs. Whitman, Flad, Meier, Mills and Smith discussed the subject, the conclusion being that nothing had yet been found which would work with careless and ignorant firemen, a fact which is equally true to-day. A standing committee was appointed in 1884 to consider the subject, and it has stood ever since. This Club was largely instrumental in the good work done in smoke abatement in this city some years ago.

CONSTITUTION, DUES, ETC.

As already explained, the original Constitution of the Club was adopted at the fourth meeting, held November 25, 1868. This Constitution, and the By-laws accompanying it, were occasionally amended in minor features, but served the Club's purpose admirably until 1885, when it seemed that the growth of the Club warranted some change in its organic law.

On October 22, 1884, a committee, consisting of Mr. Robert Moore, Professor E. A. Engler and the speaker, was appointed to revise the Constitution. This committee presented a report at the next meeting, and its discussion was made the special order for the

meeting following, November 26, 1884, when it was adopted. It has remained in practically its original shape until the present time, only a few unimportant amendments having been made. One of these forms what is now Section 8 of the By-laws, and provides for exchange of members among the Societies composing the Association. When the Club was organized there was no initiation fee, but assessments were made as the necessities of the Club required. The first Constitution provided for a standing committee of three on finances, library and publication, to be appointed by the President. It also provided for an initiation fee of $10.00 and annual dues not exceeding $10.00, to be paid quarterly, and the records show that these assessments were frequently passed over, the Club evidently not needing the funds. In 1884, after the arrangement with the Public School Library had been completed, the initiation fee was raised to $12.00 to pay for the life membership in the library. The Constitution adopted in 1884 reduced the initiation fee to $5.00, the annual dues to be fixed by the Executive Committee at the beginning of each year, but not to exceed $10.00. Assessments for special purposes may be made on recommendation of the Executive Committee by a two-thirds vote of the members present at any meeting. The total of such assessments must not exceeed $10.00 in any one year. This provision has only been used once, when the Club was asked to contribute to the support of the engineers' headquarters at the World's Fair. In 1890 an amendment was adopted increasing the initiation fee to $10.00.

The history of the Engineers' Club of St. Louis is a story of great deeds by great men. Let those of us who follow strive to maintain the high standards which have been established, and prove ourselves worthy of the honor of having been associated in the Club with some of the most brilliant minds of the century.

OBITUARY.

Archibald Johnson.*

MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

FOR a long time after the organization of this Society our ranks remained undiminished except by the occasional removal of members to other sections of the country. A few of those who have so left us are no longer living. They passed away after they had severed all fellowship, when no official notice could be taken. Our list of active and resident members remained unbroken by death until a year or so ago. But recently that relentless destroyer has been among us again, and for a second time in our history we have suffered the loss of a fellow-member. In an endeavor to take some appropriate action the task has fallen to me, Mr. Johnson's oldest acquaintance and friend, to present an outline of his work and a delineation of his character.

That friendship began over thirty-one years ago, and was never interrupted. He was then a young man, all health and vigor and full of hope and ambition, who had just entered the business world to follow his chosen profession. From that early time until his death he was a resident of this city, actively engaged in engineering work, and intimately known by all the engineers of long residence. He was a member of this Society from the second year of its existence, and took an active interest in the proceedings whenever possible for him to do so.

It is therefore fitting and proper that we should place upon our records some testimonial of our appreciation of his worth and a record of his work, for he was with us a long time and his work was important and of wide range.

Archibald Johnson was born February 3, 1841, in Ontario, and grew up on his father's farm until he entered the University of Michigan, at Ann Arbor. He graduated from the school of engineering in 1866, and received the degree of Civil Engineer. Professor DeVolson Wood was then in charge of the engineering department, while the university itself contained such men as Alexander Winchell, Andrew D. White, James C. Watson, Edward Olney and Charles Kendall Adams, all of whom were Mr. Johnson's instructors.

*By W. A. Truesdell.

Soon after graduating he came to St. Paul, under the then prevalent idea that a young and prospective engineer must look to a new country for his fortune. At that early date railroad building was the only work in progress in this northwestern country, with perhaps an occasional public land survey, and even then it was often difficult to obtain employment. Any one in Minnesota at that time ambitious to become an engineer was obliged to follow that class of work exclusively or look elsewhere for a livelihood.

The younger engineers of this Society who have come to St. Paul during recent years cannot realize the difficulties and hardships of those who were here in the early days. At times it was next to impossible to secure employment, and idleness during the winter months was generally expected. Especially in 1875 and 1876 there was nothing doing, and one could not even try to help himself. Railroad work consisted entirely in the location and construction of new lines, and no other kind was known. The services of the engineer were quickly dispensed with after the work was completed, because the operated lines were not large enough or in a sufficiently prosperous condition to require a permanent force. Whatever employment could be obtained was of a character that usually compelled the engineer to live the roughest sort of a life, surrounded by still rougher associations in camp, on the prairie or in the forest, far beyond the comforts of civilized life.

Mr. Johnson's first practical experience was on a public land survey, a service that requires more of hard physical work and endurance than of scientific accomplishments. He obtained the position of compass man with Mr. George R. Stuntz, a well-known United States deputy surveyor, who was extensively engaged in Government surveying. For nearly a year, and during the winter season, he was in the northern part of the state, and helped to run subdivision lines and part of a standard parallel.

But it was his great desire to engage in railroad work, and to build up a reputation as an engineer. Though he had made several attempts to do so, and had as often met with discouragement, he never for a moment doubted of his ultimate success. Railroad building in Minnesota was then in its infancy. The present magnificent systems were only in part projected. There were three lines reaching out from St. Paul, each for a short distance, to which additions were made piecemeal from time to time. After one season's work, in 1868, as chainman and rodman, on the Calmar division of the Milwaukee and St. Paul road, in Iowa, Mr. Johnson finally obtained the position of leveler on what is now the St. Paul and Duluth road, and during a part of 1868 and all of 1869 he was

in the employ of that company, alternately as leveler and transitman. When he obtained the position of instrument man on railroad work for the first time he was in a much happier frame of mind, and felt as if he had made a commencement at last and that the greater half of his reputation was established. It had taken him nearly two years to do this, after repeated failures, so difficult it was in those early days for a young man to get started in the business unaided and alone. From this time on his rise was rapid, and he had no trouble in obtaining employment.

When the Northern Pacific Company commenced to build westward from Lake Superior a wide field was opened to engineers, for that company maintained an extensive and well-organized staff and was liberal with its men. Mr. Johnson entered the service of that road in 1870, where he remained for two years; and during that time built up an enviable reputation as an engineer. He was employed both as a division engineer on construction and as a locater in the field. In the latter capacity he had occasion to lay down one of the longest tangents in this country, a length of 53 miles, from the Red River west. Except for the town site at Fargo, the tangent would have been over 75 miles long. On another occasion he ran a line west to the Missouri River through what was then a dangerous country to operate in, and was accompanied by an escort of troops.

In 1872 he was with the Wisconsin Central road, employed principally as a locater between Stevens Point and Portage, in Wisconsin, where he remained for part of a year.

Railroad building now came to a standstill, owing to the financial crisis of 1873, and those who had been active in that line of work suddenly found themselves out of employment, and were obliged to commence the world over again. Mr. Johnson then formed a partnership with Mr. N. D. Miller, for the purpose of engaging in private practice in this city. This partnership continued for three years or more. Besides the local work, a contract was secured and carried out for the survey of several townships of public land on the St. Louis River in this State. In 1876 the partnership was dissolved. Mr. Miller engaged with the Great Northern road, where he afterwards reached the position of chief engineer, and Mr. Johnson again went to the Wisconsin Central as division engineer on construction work in Northern Wisconsin.

Some time previous to this, or in 1874, the United States Engineer Department made extensive surveys for the contemplated reservoir system at the headwaters of the Mississippi, and Mr. Johnson was appointed assistant engineer and placed in charge of

one of the several parties that were sent out. This work lasted for one season only.

During the year 1877 he was located at Eau Claire, Wis., in superintending the construction of a dam across the Chippewa River. This work was built by contract, and Mr. Johnson occupied the position of engineer or overseer for the owners. The object of this work was the improvement of the water power for milling purposes, and to create a millpond for the storage of logs.

In 1878 and 1879 he was again on river and harbor work, as assistant engineer, in the construction of wing dams between St. Paul and Prescott, and also in charge of another extensive reservoir survey. At that time Major Farquhar was United States Engineer in charge of Government work

About this date the country began to recover from the stagnation which had existed for several years, and a wonderful era of railroad building commenced such as this northwestern country has never witnessed before or since. It would be interesting, if appropriate, to note some of the progress made during that period. Mr. Johnson located and built the Browns Valley branch of the Great Northern system, a road 40 miles in length. There is a station on that line named after him. This was in 1880.

Next he was with the Milwaukee and St. Paul road in Iowa for over a year; at first engaged in the location of new lines, and then as resident engineer in charge of the construction of 60 miles of very heavy work west of Des Moines.

This was the conclusion of Mr. Johnson's experience as a railroad engineer. So far in his lifetime he had been mostly engaged in that class of work, and though his prospects were bright for further and continuous employment, he was able to do better in another direction. He had made a reputation and was known as an excellent engineer, both on location and construction; and, furthermore, he had a great liking for the work, although he had experienced his share of the ups and downs of that precarious business. For some time previous to this it had been his desire to go further west and to acquire experience in mountain work, for he saw that a period of great activity in railroad building was about to commence in the Rocky Mountain and Pacific States which would probably continue for several years. But it was with him as it is with others; in spite of all one can do his life is apt to be governed by circumstances. It is sometimes asserted, and it may be true or not, that an engineer need not try for anything, but must accept whatever comes his way. It was not for Mr. Johnson to become skilled or experienced in mountain location, but to engage in an altogether

different line of work, and for which he was well qualified. He was afterwards able to refuse an offer from the Canadian Pacific Company. The best portion of his life was about to commence. He was yet to accomplish his greatest work as an engineer, for at that time he entered the service of the United States Engineer Department, where he remained during the rest of his life, a period of seventeen years. He soon became closely identified with the reservoir system at the headwaters of the Mississippi River, and if a history of that great work should ever be written his name would be placed prominently to the front.

Mr. Johnson's work in Iowa was not entirely completed when he was invited by Major Charles J. Allen to take charge of the improvements at St. Anthony Falls. For several years previously the general Government had been expending large sums of money to preserve the falls, and the part executed by Mr. Johnson was the conclusion of the work.

After the apron was built, long before this, the river bottom scoured rapidly, until the water was over 60 feet deep. Great quantities of rock had been thrown in from time to time, as riprap, which proved inadequate as a protection. It was all washed away in time of freshets. An examination made in 1882 showed the apron to be in a dangerous condition. The water was over 40 feet deep at the toe, where it had recently been filled to the surface with riprap; large masses of crib work under the apron had been carried out, and the apron itself had settled badly. The problem now was how to prevent this scour of the bottom and the undermining of the apron. Riprap could not be depended upon. Something heavier and more durable was required. About one-third of the water passing over the falls was concentrated at the angle of the apron, and protection at that point was the most urgent. The following plan was decided upon and carried out: First, two cribs were built and sunk under the foot of the apron, to serve as a support and to replace those which had been washed away. One of them was 26 feet wide, 67 feet long and 28 feet deep, filled with rock. Next a portion of the river bed 90 feet square in the angle was leveled up with rock, until the water was exactly 24 feet deep. This was a foundation for the work which followed. A crib was now built in the river near to the place required. This was 80 feet square and 6 feet high, constructed of heavy timber and well bolted together. When completed it was floated to its position in the angle, filled compactly with rock, thoroughly grouted and covered with a heavy flooring. A curbing of plank 16 feet high and watertight was now built upon the crib, braced from the interior, and the

whole structure was then sunk to its place on the river bottom by admitting water through the gates at the corners of the curbing. After it had reached its foundation the curbing was detached, and large quantities of heavy stones were placed around it to hold it in position.

Mr. Johnson was engaged on this work nearly a year. In his report of 1883 to the chief of engineers Major Allen says that the success of the scheme was mainly due to Mr. Johnson's skillful management. A description of the plan and its execution was afterwards read by Mr. Johnson before this Society, and was published, with illustrations, in the Association JOURNAL of July, 1888.

When the work at St. Anthony Falls was completed Mr. Johnson was sent to Grand Marais, on Lake Superior, where he remained until the close of the season directing the improvements of that harbor, which consisted mainly of crib work and dredging.

Two years or so previous to this work on the reservoir systems had been inaugurated by the general Government, and two of the dams of that system were just completed,—those at Winnibigoshish and Leech Lakes. The object of these dams is the storage of enormous quantities of water collected during the spring and early summer, to be systematically released so as to benefit navigation below the dams and as far down the river as Lake Pepin during times of drouth and low water.

A third dam was about to be commenced at Pokegama Falls, near Grand Rapids, which was to serve as a distributing reservoir for the water coming down from the two dams above, which, together with the Pokegama dam, have a storage capacity of over 80,000,000,000 cubic feet of water. Mr. Johnson was given sole charge of the work, and remained there a year or over until it was completed. This dam was built of timber on a rock foundation, and is about 200 feet in length and 14 feet high.

His next work was the Pine River dam, the fourth one of the system to be built. Pine River is a tributary of the Mississippi, entering just above Brainerd. The object of this dam was simply to create an additional storage of water, which is 7,000,000,000 cubic feet. Its whole length, including crib work, dikes and embankments, is 1500 feet, with a lift of 17 feet. The dam itself at the river is 235 feet long and 26 feet wide, built of cribs, filled with stone and all resting on a pile foundation. It contains fourteen sluices and gates. There is a trench in the foundation reaching across the river which is 14 feet deep, filled with clay and capped with concrete. Supplementary to this work a dike was built at the south end of White Fish Lake, which is a part of Pine River reser-

voir. This dike is 167 feet long, 13 feet high and 10 feet wide on top, with slopes of three to one, and all of it riprapped.

For the next five years no new work was commenced, owing to a lack of appropriations, and during that time Mr. Johnson had general charge of the whole reservoir system. In pursuit of his duties he visited all of the dams as occasion required, attending to whatever repairs were necessary, but mainly concerned with their operation.

To render the Pokegama dam and the two others above more effective it became necessary to build a fifth, the one at the mouth of Sandy Lake River. This dam creates an additional storage of water, but its main object is to prevent the Pokegama discharge from backing up into Sandy Lake and spreading over a large extent of country, instead of reaching its destination below St. Paul. The Sandy Lake dam is one of the most important of the system, acting as a supplement to those above, although it is only 12 feet high. It is built of crib work, filled with stone, on a pile foundation. There are six sluices and a navigable pass or lock 40 feet wide and 249 feet long for the passage of steamboats. The work was commenced in 1891, and Mr. Johnson was stationed there two years or over, but at the same time retaining his supervision over all the other reservoirs.

No other dams have been built since that at Sandy Lake, although a large number more are contemplated. From this time on Mr. Johnson usually spent his summers in the northern country wherever his presence was required, and the winter seasons at office work in St. Paul.

The last river and harbor bill contained a large appropriation for repairing the two dams first constructed, and early in the past summer he made what proved to be his last journey to the reservoirs to superintend the work. All of the summer and a part of the autumn he was at Winnibigoshish rebuilding the superstructure of that dam. While so engaged he was suddenly stricken with typhoid fever in the latter part of September, and, though he was brought to St. Paul and everything possible done for him, his constitution, which had been impaired by the hardships and exposures of his earlier life, could not withstand the severity of the fever, and he died October 3, after a short period of sickness.

So ended an active life of over thirty-two years' duration, the first fifteen of which was mostly devoted to the laborious business of a railroad engineer and the latter part to some of the most important Government work that has been done in Minnesota.

From his first river and harbor work in 1874 to his death was a period of twenty-five years, during which he was associated with four United States army engineers. At first Colonel Farquhar, then with Major Charles J. Allen; next for eight years with Major W. A. Jones, and lastly with Major F. V. Abbot, all of whom he served faithfully and well. During most of this time he occupied as high a position as a civilian can attain in the Government service.

In May, 1870, he was married to Miss Marion Bliss, of Ann Arbor, whom he first met when a student at Michigan University. His only child, a son, died about three years ago, in his twenty-fourth year. His widow survives him.

Mr. Johnson was an active and interested member of this Society, and did his share of literary work and often engaged in the discussions. He was not a charter member, because he was at Grand Marais when the Society was organized, but he became connected at his earliest opportunity. His first paper was on the "Preservation of the Apron at St. Anthony Falls," and was published in the Journal. Four years ago he read another on "The Bear-Trap Gates at Sandy Lake Reservoir." This was printed in the Journal of June, 1896, and formed one of a series of eight very able papers written by United States engineers, civil and military, on the subject of "American Hydraulic Gates, Weirs and Movable Dams."

It is not a difficult task to estimate Mr. Johnson's standing as an engineer, or to give a presentation of his personal character. There can be but one opinion about the first, which must be founded upon his long and creditable record. He was easily understood by those who knew him best, for his traits of character were strongly defined; and he was a man who always passed for just what he was, no more and no less. His positive convictions, always expressed without fear, together with his sincerity and earnestness, which were predominating features with him, precluded any analysis of his character but the correct one. This opinion of him was entertained by all those who had his acquaintance, for he impressed all alike with his individuality. He possessed one faculty in particular which was marked and unusual, the power of making friends, and, what is better, of keeping them. During his whole lifetime, wherever he was located or whosoever he was associated with, he was well liked and popular. The number of his friends was limited by that of his acquaintances.

Mr. Johnson was an engineer in every sense of the word. There are always three requisites necessary to make an engineer: Good practical sense and judgment, the proper education and ex-

perience. He possessed all of them to an unusual degree, for he was a man of excellent judgment in his work, careful and with correct opinions. He had received a first-rate mathematical and technical education, and, without in any way being a bookworm, was always a student. He was well read and informed outside of his profession, and with his friends was an intelligent conversationalist. His small but well-selected library contained such works as Stoney's "Theory of Strains," a French edition of Morin's "Hydraulics," Peirce's "Analytical Mechanics," the masterpiece of America's greatest mathematician; Hardy's "Quaternions" and Darwin's "Descent of Man" and "Origin of Species."

As we have seen, his experience was varied and extensive. He was successful in whatever he undertook. He had little to do with commonplace or routine work, but was always connected with something of magnitude and importance, and his name is invariably associated with work of that character.

During his whole professional life he was a man who stood solely on his own merit. He never obtained or held a position except by that one virtue; he was never aided in any manner by favoritism or influence, political or otherwise. There was nothing of the wire-puller or politician in his makeup. He started out in life with the idea that whatever success was in store for him must be a result of his own professional ability and competency, and he always retained that idea. Perhaps he did not take sufficient note of tact, or policy or of personality as elements of success. He invariably gave the fullest satisfaction to those he served, and they in turn were ready to recall him should occasion require it. He was always known as a competent engineer, perfectly able to accomplish whatever he undertook, and a most reliable and substantial man.

There was nothing pretentious in his manner, and any narrow trait was foreign to his character. Though he was far from overestimating his own ability, he was conscious of his real worth, and careful and jealous of his reputation. In this city his acquaintance was confined in a great measure to the engineering fraternity and to those who come in contact with that class of men, but in the northern part of the State he was widely known. He was never in a public or conspicuous position, and had no newspaper reputation whatever. His work was always at a distance, away from the public gaze, and could not receive that appropriate attention which it deserved. It might be said of him with regret, and it would be true of all engineers, that he and his work were too little known outside of his immediate circle.

Nevertheless, he was an ideal representation of the true engineer, for he belonged to that class who elevate the profession. His name always carried confidence with it, and was everywhere and at all times mentioned with respect, because it was synonomous with good work. He was one who went through the world doing his duty faithfully, honestly and creditably, without noise or ostentation, and received as a reward the praise of his own satisfaction and the esteem of his fellow-men.

SAMUEL NOTT.

Secretary, Boston Society of Civil Engineers, 1849 to 1874.

ASSOCIATION

OF

ENGINEERING SOCIETIES

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THE OUTLOOK FOR ENGINEERS.

ADDRESS BY C. FRANK ALLEN, RETIRING PRESIDENT, BOSTON SOCIETY OF CIVIL ENGINEERS.

[Delivered at the Annual Meeting March 21, 1900*.]

IN the by-laws of some of the engineering Societies of this country it is prescribed that the President shall present an annual address. For this Society there is no such requirement; neither can there be said to be an unwritten law to this effect, for the practice here is not uniform. Nevertheless, it may fairly be stated that there is in many quarters some expectation that the program for the annual meeting shall include an address by the retiring President. That one should be presented seems to me desirable. It is not uncommon to utilize this opportunity for retrospect over some part of the broad field of engineering, while at times an attempt is made to secure some outlook into the future; and it is largely in the latter direction that your attention is directed this evening, although this course involves some consideration of the status of the engineer at the immediate present and for the early future.

During the last twenty years the membership in the Boston Society of Civil Engineers has increased from 94 to 490, an increase of 421 per cent.; while the population of Boston has increased about 50 per cent., and that of the State perhaps 53 per cent. During the same time the membership in the American Society of Civil Engineers shows a change from 599 to 2221, an increase of 271 per cent., while the population of the United States shows an increase of only about 56 per cent. Looking in another direction, the number of graduates in civil engineering from a well-known engineering col-

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lege in Boston has increased 192 per cent., the average for the period 1870 to 1879 being 8.5, and for 1890 to 1899 being 24.8. From the same institution of learning the total number of graduates in engineering, including civil, mechanical and mining, was 17 in 1879; the total of graduates in engineering in 1899, including students in civil, mechanical, mining, electrical and chemical engineering and in naval architecture, was 126, an increase of 641 per cent.

There can be no reasonable doubt, especially in view of the figures quoted, that the number of civil engineers has, in twenty years, increased in a measure far beyond the increase in population during the same time. To what cause shall we attribute this increase? It is a fact well recognized in transportation matters that improved or increased facilities are met by a definite and generally an emphatic response in the way of patronage. Changes from horse cars to electric or cable lines, to elevated or to underground lines, are met in each case by increased travel to an extent that has evident relation to the extent of the improvement in the quality and quantity of transportation offered. In trade an improved product of any sort prompts an increased demand. So with the engineer, an improved quality of engineer creates for itself a demand greater than before existed. This is exemplified most fully probably in the case of the electrical engineer, who had hardly come into being twenty years ago. The discoveries as to the possibilities of electricity for practical uses and the perfection of apparatus for using power electrically transmitted have been the work of the electrical engineers, who have thus almost absolutely created the opportunities which have been used to still further enlarge the field open to electrical engineers. In a similar fashion in transportation, the improvements in transportation facilities have been largely the work of engineers. The increased patronage results in a demand for transportation facilities greater in quantity, and of a quality requiring often a higher order of engineering ability than seemed adequate before; and so the engineer in transportation extends the opportunities open to himself and to his fellows alike. Here, too, the improved quality of engineer brings about the increased demand. In municipal and sanitary engineering the influences can likewise be traced. The higher standards of the communities as to sanitary matters, which engineers have done their full share to create, and the more perfect means of securing better sanitary results, for which the engineer is mainly responsible, have led to the adoption of desirable, now almost necessary, sanitary improvements which could not have been effected except through the existence of the

higher standard and through the possibility of securing works more effective for the desired end. At an important investigation within the last twenty years a question was raised as to the possibility of determining by mathematical analysis the adequacy of a certain detail of construction then under discussion. Among several questioned one engineer only was familiar with the method which would yield correct results. With reasonable promptness this man was called to fill an important position, the necessity for which had not previously been apparent. To a very considerable extent the engineer does create in such ways his own opportunities.

If, then, we may consider it established that the demand for engineers is in large part due to the fact that we have in our engineers of to-day a better product than we had in those of twenty years ago, in what does the improvement consist? It can hardly be claimed, seriously, that so marked an improvement shall have occurred in the native ability of the young men of this country in a space of time quite within a single generation. It is, however, possible and rather more than probable that more young men of superior ability have of late been attracted to the pursuit of engineering occupations. This fact, if it be one, is, however, not antagonistic to the further proposition that the product, the engineer, has improved in quality partly because of his superior training in those things which are fundamental to correct engineering practice and partly because it has been possible for him to acquire a wider, fuller knowledge of facts and methods employed in engineering; these two factors, theory and experience, combining with natural aptitude to furnish the finished product, the true engineer.

Among the influences which have contributed to the improved quality of engineers, perhaps the most important are the engineering college and the engineering society. Probably the first in importance in its influence upon the engineering profession is the engineering college. There is required for the successful engineer, as suggested above, first, natural aptitude and capacity; to this must be added, second, a foundation training in theory requisite for the handling of engineering problems likely to come to the engineer for solution, and this must be supplemented by, third, experience, or a knowledge of facts, methods and details that are essential for the proper treatment or solution of such problems. That the engineering college should furnish all of this is neither to be expected nor is it desirable. The experience necessary can be furnished neither in quality nor in proper quantity by it. Its most important function is in the direction of doing for the student those things which can be accomplished, if at all, with greater difficulty outside the engi-

neering college. In this way it must secure to the prospective engineer a suitable knowledge of, and a thorough training in, theoretical work, and this is, in fact, the work primarily undertaken by these educational institutions. It is found, however, that with most mortals, as directly regards theory, training of the proper sort is secured with difficulty, or not at all, unless the application of theory to practice is closely established. It is further found by these engineering colleges that a training in theory is of little value to the would-be engineer, unless he can somehow be put into a position where he can secure that additional experience necessary to make him in a full sense an engineer. In order to secure for its graduates who are well grounded in theory, positions in engineering work where experience of the proper sort and amount can afterwards be secured, it is found desirable and necessary to give to the student a knowledge of the facts, materials and methods of engineering sufficient to furnish an experience which shall unite with his theory in making him at graduation, in some sense already an engineer, sufficiently so that he becomes at once of some immediate value to his engineer employer, and in many cases with only brief additional experience a valued member of an engineering corps. However much opportunity there may be for improvement in their management, it is substantially an established fact that the best engineering colleges do at present furnish graduates who are prepared sufficiently well so that engineering employers (non-graduates as often as graduates) generally employ technically educated young assistants simply as a matter of course.

It should be recognized, however, that the value of the technical graduate depends not altogether upon the education which has been given him. Another factor not always appreciated is that the engineering graduates are men carefully, and through a long process, selected as to native ability. The boy in the country village who has shown some taste for mathematics and some aptitude in a mechanical or constructive direction is not only the boy by nature fitted to become an engineer, but is probably the boy for whom an engineering education becomes more than a suggestion,—becomes a most welcome reality. It not infrequently happens in this way that the boy who thirty years ago entered mercantile pursuits rather than incur the burden of a college education in the direction of languages and literature, for which he had no marked taste, now sees his way clear to secure an engineering education whose outcome seems to offer satisfaction as a general liberal education, as well as to promise immediate and agreeable business opportunity. As an alternative the college of engineering tends somewhat to

divert from these colleges granting the A.B. degree many promising students whose ability to reason develops a taste for mathematics, for mechanics, for chemistry, and fails to attract those students whose more perfect memory and lack of scientific taste naturally lead to the study of language, of literature, of history. The engineering college does more, however, in sifting out the chaff from the wheat, for of those who present themselves for entrance examinations it may happen in some colleges that only about one-third find it possible to reach the point of graduation, although not all of the two-thirds who drop out do so from lack of ability or failure in performance of their duties. At the present time, then, it must be true that the graduates in engineering are, on the whole, a selected class, both from the point of view of natural ability and thoroughness in training. In addition, the graduate should have acquired habits of earnestness, the power of concentration and the ability to attack new problems.

It should not, however, be hastily assumed that the man sifted out during the process of education is to be a failure as an engineer. Sometimes through an aptitude for mastering the practical details of engineering and the possession of a large degree of what is often described as horse sense; sometimes by virtue of natural ability obscured by the tardy development which sometimes characterizes whole families; sometimes because the natural ability which exists has not been supplemented by adequate teaching in preparatory schools; sometimes because a consciousness of a failure to have improved his opportunities at last acts as a spur to a young man who has at first failed to realize the mettle that is in him; from some cause or another, it frequently happens that the non-graduate who drops out at the wayside does outdistance his classmate graduates. This, however, must be the exception to the rule.

Neither should it be assumed that by way of the engineering college is the only path to success in engineering. It would, in my judgment, be unfortunate if this were true. Within the field covered by the general membership of this Society many of the most important works have been designed and constructed by engineers not thus educated. To the young man of natural ability and aptitude more than one road to engineering success is and will be practicable. Success comes to such engineers in most cases, however, by virtue of the acquirement by them at some time and in some way, of those principles underlying the science of engineering which could more readily have been acquired in the engineering college if its advantages had at that time been open to them. Most of these self-trained successful engineers are, however, to-day

the first to recommend to others the education offered by the engineering college, as well as the first to secure for assistants engineering graduates when it is possible to do this. Of engineering education it has sometimes been said that the value of the instruction given by a teacher is measured by the amount of individual effort required from the student. It has also been thought by some that the instructor can do little in the way of direct teaching. His results are reached by setting the student at work, the instructor's function being only to properly direct the student's efforts. If these propositions be true, and they are certainly not entirely in error, the self-trained engineer, with less of teaching and more of personal effort, travels a far more rugged road; but, if finally successful, has often developed a mental fiber, has secured an originality and a fertility of resource and has come into possession of a proper self-confidence as to his ability to master obstacles; qualities all of them well-nigh essential to the engineer, and which under indifferent formal teaching in the college might fail to receive proper cultivation. If it shall happen in some instances that the graduate feels that his goal is reached and further study unnecessary, in this case, too, the self-trained engineer, by slower process, may readily run abreast and soon after far outstrip the graduate. In my judgment, then, it is quite unsafe, and will continue to be so, to assume that a failure to have attended an engineering college is a proper point of criticism against an engineer in individual cases. Nevertheless, for the future the opportunities for employment and development for office-trained or self-trained engineers will be far less favorable than in the past, and the better positions will be mostly held by the graduates of our engineering colleges. In any case, the standard of acquirement necessary for the successful self-educated engineer will be largely determined by the curriculum of the engineering colleges.

Second probably in importance are the engineering societies, which serve several important functions. Through their medium the experience of one becomes in many cases the experience of many. In the papers presented before the various societies of engineering, among which may with some propriety be included water works associations, railroad clubs and highway associations, at present the tendency is to the description of methods and facts connected with engineering construction, rather than to the discussion of advanced mathematical theories. So far as this is considered an important function of the engineering society, it serves admirably to supplement the engineering college by furnishing in an excellent way much of that experience which is necessary

to the young man before the term engineer can properly and fully be applied to him. That many of the papers read call attention to well-established theory adapted to new features of practice, and that new points of theory will be connected with successful practice, goes without saying. It is true also that, first and last, many papers, as a matter of fact, are strong expositions of mathematical theory in advanced or unusual fields of inquiry. The effect of the engineering society, however, in increasing the abilities of its members is not to be measured altogether by the value of the papers presented. Who shall say how much is gained by the power of absorption by one who finds himself in the engineering atmosphere which prevails in the meeting or the excursion, at the "engineers' table" or in casual meeting on the street or train? How shall we measure the gain that comes from opportunity to observe the attitude or habit of mind of various engineers towards an engineering question under discussion? What measure of good to engineering in general, as well as to the individual engineer, comes from the fact that the younger engineer has an opportunity to impress upon the older engineers the ability which might otherwise be much longer hid under the bushel? What from the opportunity that is given to the chief engineer of new work to have tested something of the caliber of the young man who is a possible assistant? Is it easy to estimate the good that comes to engineering when engineers are ready either in the meeting or in the office for an interchange of knowledge of facts or experience in minor matters, or are prepared to recommend the employment of their neighbor as consulting engineer when extended investigation or completeness of design is required? To what extent do individuals exert themselves in the interests of another who has been the victim perhaps of political discrimination, doing this as a matter of professional, rather than personal, friendship? In what measure is public confidence in engineering stimulated by the existence of large and well-organized associations of engineers, many of whom are already widely known as men of superior ability? In various ways the engineering society is a powerful element for the betterment of the engineer individually and the advancement of engineering in general.

Much that has been stated with relation to engineering societies is also true of the engineering periodicals, many of which are doing work of exceptional value. Occupying a somewhat different field from the society journal, the engineering periodicals are likely to present contributions somewhat more fragmentary than the publications of the societies, but, on the other hand, rather broader in their scope. They reach, moreover, many whose remote location

serves to prevent attendance and even to discourage membership in any of the engineering societies. As a commercial venture these periodicals naturally excel in enterprise, and from this cause also contribute much to the cause of engineering development and progress.

The engineer, ideal and actual, being substantially what the conditions and opportunities outlined above have made him, being such largely now and to become more fully so for the early future, what is the outlook? What field is he to occupy? In what will this differ from that now ready for him? For what is he especially fitted?

To my mind it will be realized by the engineer and demanded by his clients or his employers not only that the works designed and constructed by him shall be safe, convenient and appropriate, but also that they shall be economical both in cost of construction and in cost of operation if possible; but, in any case, economical in the resultant of these two items if both be not attainable together. The client is content to pay large fees to the lawyer who either secures for him a large sum of money or saves him from paying heavy damages; the patient feels deeply indebted to the physician who saves his life or relieves pain. It is too easy for the client of the engineer to be conscious only of a large outlay of money to which the engineer's fee becomes an unwelcome addition, a necessary evil. The engineer will occupy his proper position before the public and with his clients or employers only when it is appreciated that money is saved by his employment. In other words, when he is employed not merely because construction of any sort is impossible without him, but more directly because the corporation or individual who employs him cannot afford to do without him. It will be true in the future to a far greater extent than in the past that much will be demanded from engineers on the economic side, and that engineers will better appreciate the necessity for more efficient work in this direction. A better training in theory, the opportunity for a wider knowledge of the experience acquired in any particular department of work, greater certainty as to the behavior of many materials used in engineering; these unite in making it possible for designs to be made with less margin for error or uncertainty of information, and render possible greater regard for economy. The engineer of the future who is a better product than the engineer of the past in this particular will surely find an increased demand for his services, and will render even a greater service to the world and do his part in bringing engineering to its proper higher level. The higher position which the engineer is to occupy in the future will be due largely to his true worth.

It seems to me that an entirely legitimate field for the exercise of engineering lies in the work of execution as distinct from the design or supervision of construction; in other words, in engineers occupying positions as contractors for the carrying out of engineering work. Is it not often true that the method of execution is a matter of as great importance as the final result? Is not the handling of the work often of greater difficulty than simply furnishing an adequate design for the completed structure? In the case of the Boston Subway, a problem of perhaps greater difficulty than merely securing a successful result was the adoption of methods which should avoid undue interference with traffic on the streets. The success of the early modern cantilever construction in the Niagara bridge lay not merely in an economical result, but equally in the method of construction. Illustrations could be multiplied if it were necessary. It goes without saying that more economical and better results would generally be secured if the more important parts of contract work were to be performed by men well trained both in the theory and practice of engineering, a training which should include a thorough understanding of the properties and behavior of the materials of engineering, the training which the engineer of the future must have. A familiarity with engineering literature would often prove of extraordinary value to the contractor for many classes of engineering work. It is a notorious fact, too, that many contractors now moderately successful in business have an entirely inadequate knowledge of the cost in detail of the different items entering into a large contract, and are not well adapted by education to acquire ability in that direction. It is now quite common, as we know, for contractors to consult engineers in such matters. The better preparation possessed by the engineer, and hence a superior ability for handling work, together with a more adequate knowledge of the probable cost, would lead to two results of importance to engineering: First, the actual cost of work to the contractor would be less, resulting in the long run in lower prices; second, in fewer cases would the bids be found improperly low with the attending difficulty of securing the proper quality of work. The few cases of actual saving from bids too low would be counterbalanced by a more even margin of profit all along the line. The contractor trained as an engineer would by acquired temperament be disposed to maintain a higher standard of performance than is the case with the ordinary contractor. A very high standard, as we know, is now maintained by many firms which construct pumping machinery under contract, as well as by the more prominent engineers who contract to build bridges under definite

specifications and as the result of competitive bids. Many other examples will suggest themselves. There is no opportunity for question as to the fact that in certain lines of engineering work the engineering contractors have been among the most able, the most respected engineers in the country. There is opportunity for engineers of high professional standards in many other branches of contract work which are now not altogether, but are yet too largely, in the hands of men skilled in handling men rather than educated and trained to the proper execution of engineering work. I believe it important that engineers should feel that they are supported by the best engineering sentiment if their tastes and abilities lead them to become contractors for the execution of engineering work, and that they shall consider themselves to be accepted members of the engineering fraternity.

There is another field which has so far seemed less attractive to engineers than seems to me wise and proper. The filling of executive positions by engineers is far less common than it ought to be. Instances, to be sure, are not altogether rare where engineers have become presidents, general managers or superintendents of railroads, superintendents of water works, treasurers or superintendents of mill corporations, presidents or important executive officers of mill insurance companies, or at the head in some way of business establishments in whose conduct a knowledge of engineering is of definite and important value. For executive railroad work my own opinion finds able support, that the most desirable preparation is an education in civil engineering of the sort furnished by many of our engineering colleges. Aside from the acquirement of an acquaintance with much of a technical engineering nature which will be applicable to many parts of railroad work, the quality of the training secured is of superior importance. In the study of mathematics and of science one has engrafted upon him the feeling that error cannot result in truth, that wrong at the beginning cannot well bring forth right at the end. The training of the engineer tends strongly throughout to secure that honesty of attitude which is the common characteristic of the engineer. A prominent journalist of this country has put it that an engineering training brings a man to the point where he is able to look a fact in the face. The engineering training tends towards the production of a logical mind. The constant demand upon the engineer is to adapt means to existing conditions, to study cause and effect. The logical outcome both of the training and the practice necessary to his success is to force the engineer to stand upon his own judgment; to develop decision of character, firmness, courage, qualities of direct value in any

executive work. These qualities, combined with the technical training and experience in the affairs to be dealt with, have led, in the case of some railroads, to a general policy in favor of promoting their civil or mechanical engineers to the important executive positions. What has been the policy of certain railroads may well become the policy of many others, and may well become the practice, too, of many manufacturing and other corporations. To the comment often made that administrative positions become the reward of those who have natural executive ability, it may be answered that executive ability is in part only inherited; it is in part acquired. The ability to have work well performed by others depends in part upon a suitable technical knowledge of the work itself; it depends in part upon clearness of vision and decision of character, and these may readily be the development or result of the engineering training, including both education and experience. Executive ability depends in part upon a natural tact in dealing with men, in judging character and in systematic business habits. That engineers should as a class be inferior to others in these particulars is improbable, unless it be true, as it sometimes appears to be, that the engineer allows his interest to become very largely absorbed by the scientific or purely engineering problems of construction with which he has to deal, and to an extent which renders it difficult for him to give much attention to the business conduct of the projects after completion. To my mind, it should be considered the legitimate function of the engineer to occupy administrative or executive positions for which his previous training furnishes a reasonable preparation; and those young men who seem to have natural tastes and abilities in such directions might well make a special effort to acquire an insight into business methods and to develop ability in character reading, and thus to train themselves for the position which is likely to seek them if they are ready prepared for it. The rewards in such positions are likely to be adequate, and an engineer's loyalty to engineering may find solace in the fact that he may frequently find opportunity to further advance the interests of pure engineering for the benefit of other engineers. To my mind, it is clear that the engineering training would prove an admirable preparation in many lines of work, even where there is little opportunity to make use directly of engineering knowledge. I have strong reason for feeling satisfied that the logical habit of mind and directness of method characteristic of the engineer furnish a splendid equipment for the study and practice of the law; and what is true of law is true also of many lines of work.

It remains, finally, for me to say something as to the salaries or fees to be paid to engineers. Is it not reasonable to assume that so far as engineers as a class become in fact more able, and their ability on the economic side becomes appreciated, in like measure their services will command more adequate payments? To secure the best results in this direction it is necessary that men of prominence in engineering practice should come to a just appreciation of the dignity of the engineer. Engineers of much prominence are, some of them, sinners against what should be considered the ethics of the profession; not only in standing ready to work for less than adequate fees, but also in scaling down to the lowest point the wages or the salaries to be paid to subordinates. Is the dignity of engineering upheld when engineers in charge of work for large and financially able corporate interests endeavor to secure graduates from colleges of engineering for eight or nine dollars per week in positions where there is little opportunity for advancement? What effect has it upon engineering progress when a chief engineer pays such a graduate nine dollars per week at the start, and after a year or two of successful service, devoted in part to the successful design of important features of the work, tells the young man that his application for twenty-four dollars a week cannot be considered; that it is acknowledged he is doing a higher grade of work than his rank indicates; that his services are satisfactory; his worth is equal to the amount demanded, but there are other employes of similar rank and it had been decided that no salaries can be raised, and that his present salary of twelve dollars per week is the maximum possible for some time? Does it pay to secure the lowest-priced engineer you can find, even in subordinate positions? Is it not better to pay more than the minimum and insist upon having men not below the average in ability? Is it not worth while to pay enough to a good man to keep him if he has proved his worth? Does the employer appreciate more highly the chief engineer who by his own acts announces that an engineer is an engineer, and the more cheaply you get one the better? To me it seems that it is a mistake to buy a car wheel at a price too low to allow of good material, and at least equally a mistake to try to secure an engineer at a price too low for a superior article. In a similar way it seems to me that an engineer, unless under severe financial straits, should be unwilling to accept a position at a figure inadequate for the work demanded of him. The young graduate can properly, of course, for a time accept work at a nominal salary, provided the experience to be gained and the opportunities for advancement are in themselves valuable. The older engineer, whether in the case of salaries,

or retainers or fees, should see to it that he is not the one to encourage the lowering of the standard of payment for the work done by him. For many years I have held in the highest admiration the action of a personal friend who refused to accept the position of chief engineer of an important railroad then under construction at the salary he was already receiving as locating engineer, two hundred and fifty dollars a month. He was willing for a time longer to serve in his old position as locating engineer, but not at all as chief engineer at what was in fact, under all the circumstances, an inadequate salary. A few years before, while waiting for a mining camp to develop, this engineer had taken his shovel and worked at day's wages on a toll road, although then possessed of money sufficient to loan a moderate sum to the contractor, who needed ready cash. The splendid fellow who did not hesitate to work as a day laborer was yet above accepting a position of dignity at undignified wages. His refusal, as a matter of fact, delayed his advancement only for a short time, for he soon secured an equally good position elsewhere at terms which he could accept. I have never doubted that his action was entirely proper, and I believe that the general status of the engineering profession is more dependent than many have supposed on the attitude assumed by prominent engineers themselves as to the rewards of engineering; both those demanded by them of others, and those granted by them to subordinates. This Society has in its power to exert through its members a strong influence for good in this as in many other directions. If my views upon the various points presented are sound, this Society can by the general attitude of its members do much to aid in a broader development of engineering and to secure for engineers a better recognition from the public than has heretofore been accorded them. To help bring about such a result is the purpose of this address.

ENGINEERING WORK IN LOUISIANA.

Address by Thomas L. Raymond, Retiring President of the Louisiana Engineering Society.

[Presented at the Annual Meeting January 13, 1900.*]

We celebrate to-night the second anniversary of the birth of this Society. By a constitutional requirement I am obliged to deliver, and, by a liberal interpretation of our fundamental law, you are bound to listen to, a presidential annual address. Though only two years old, the Society has learned to talk in a disjointed sort of way, but I trust as she grows older the list of her wise and practical sayings will enlarge to a degree commensurate with the knowledge and talent which I feel sure she possesses. Your first President in his annual address most instructively entertained us by tracing the development of engineering and the kindred professions represented among us, through historic ages, describing for our instruction the greatest works of all countries.

To gather up the threads of his narrative where he left them fluttering in the storm of progress in the methods of controlling and utilizing nature's forces, which has swept over the world during the latter half of this century, and to weave them into a tapestry which would portray the advancement in a single department of our work during this remarkable period, would be a task greater than I would dare or your endurance brook. Disclaiming, then, any effort to take up the subject of my predecessor in a consecutive way, I have thought it might serve some useful purpose to note as carefully as possible the "Achievements of the Engineer in Louisiana in Recent Years."

The departments in which the engineer has been most conspicuously employed in this State, since the active recognition of our needs began, have been in the designing and construction of levees, railroads, river and harbor improvements, street railways, electric conduits, manufactories, modern building and mining. In this list the attempt has been made to name the works in sequence of magnitude, and I propose to comment upon them in the order given.

LEVEES.

When it is remembered that the whole or a large part of thirty-five parishes of the State, or an area of 16,000 square miles, lies below the yearly flood surface of the great streams which carry the

*Manuscript received January 17, 1900.—Secretary, Ass'n of Eng. Socs.

drainage of about one-half the area of the United States through Louisiana to the Gulf, some idea may be formed of the magnitude of the task of rearing embankments to retain these waters within limited channels. But the facts are even more startling, in that there are 1200 miles of levees now in existence, ranging in height from 3 feet to as much as 35 feet, built through fields, forests and treacherous cypress swamps; that many great dikes cross old river beds and sloughs, where the weight of the embankment has displaced the underlying slush 10 and 12 feet deep before reaching the point of equilibrium; that the encroachments of the rivers upon the banks has necessitated the rebuilding on new and safer locations of many miles of this system, and that the greater part of all this has been done since 1882. Previous to that year the levee engineer was struggling most manfully against hope, with totally inadequate means, to patch up here and there the weakest part of the frail line, dreading alike the terrible months from January to June, when he knew that somewhere the line must give way, when the water at New Orleans reached a point 6 feet lower than he now provides for, and that equally terrible time when the low water in the treasury would leave his salary high and dry upon a sand bank, only to be floated to him by the piratical broker after the usual salvage claims had been met.

Since 1882, with the added assistance of the National Government, means to execute his plans have been given him in some degree commensurate with the magnitude of the work, and the results achieved have been stupendous. He has built up 85,000,000 of cubic yards of earthwork in the State, covering a length of 1200 miles, and has practically demonstrated, in spite of the protests and obstructive tactics of many sincere but uninformed doubters, the efficiency and wisdom of the levee system by finally and completely controlling the greatest flood ever discharged by the Mississippi. The earthen embankments now protecting the lowlands of Louisiana from overflow would be sufficient to add 4 feet of filling to the area of this city, embraced between the limits of upper protection levee and Elysian Fields street, the river and the ridge, or, to illustrate in another way, would equal in contents two-thirds of the great wall of China, which is reported to be 1500 miles long, 25 feet high and 20 feet broad. Our barriers protect us from a more ruthless enemy than the Tartar ravagers of the Celestial empire.

In the construction of these immense dikes the engineer and contractor, working together, have progressively improved their methods from the use of the wheelbarrow up through the drag and wheel scraper to the levee-building machine, until now the use of

machinery in the construction of levees is almost an assured fact. The result has been that the price for the average embankment has declined from 50 cents and 60 cents per cubic yard, as in the good old times, to less than 15 cents in 1898.

It has been the custom of the levee engineer to deprecate the professional value of his work (the unfortunate characteristic of all engineers) as being only a matter of piling up dirt, but when we consider the close and eminently scientific study he has given to the flood slope problem, designing his grades carefully to predicted height, his knowledge of caving bends applied to the location of his line of defense, and his design of cross-section to meet the special requirements of strain and economy of material in a given location, it cannot but be conceded that in this branch of the profession, the engineer in Louisiana has added much to the record of engineering achievement and accomplished a work which will rank among the greatest of the century.

RAILROADS.

It is in the recollection of many of us, not the oldest, when the Great Jackson, the Opelousas and the old and unreliable Pontchartrain were the only railroads in the State. The first ran over the border at the first opportunity; the second boasted of only about 160 miles of track, and the last was and is only five miles long, and usually five minutes late. The State for many years lagged behind the rest of the country in railroad construction, but development has begun and bids fair to place us in a few years well up in the front rank of railway mileage. To-day New Orleans is the terminus of four great lines connecting us with the great East and yet growing West, as well as of two trans-continental lines traversing the whole breadth of the State on the way to the famous "open door" for which the world is struggling. In 1870 our mileage was only 450, to which the ten years to 1880 added only 200 miles, while in 1898 the State could boast of 2274 miles of track, more than any one of the New England States possess, thus placing us in advance of twenty other States of the Union. Since writing the above I have learned that in 1899 Louisiana has added 150 miles to her roads, and stands eighth among the States in mileage added.

While the railroad engineer finds no mountains to climb nor tunnels to bore in his construction here, yet there are other problems which have been solved peculiar to the delta formation of our soil, and this has been accomplished largely by the force of trained ability, unsupported by the all-comforting precedent. The roadbed of the New Orleans and Northeastern Railroad was constructed,

for example, through the so-called trembling prairies by carrying the track on a pile trestle for 21 miles, filling to the bottom of the rail later, from a pit not nearer than 50 feet from the ties, by means of a special conveyor dredge; then, after removing caps and stringers, the road was ballasted and a consolidated roadbed obtained in the ordinary way. The 6-mile trestle across the end of Lake Pontchartrain is built on creasoted piling, which drove 1 foot at the last blow of a 3000-pound hammer, and not a single bent has ever settled.

These are noteworthy departures from practice elsewhere recorded, bold in execution as well as successful in result.

The Texas and Pacific bridge piers in the Atchafalaya, so well described in a paper read before this Society, are worthy of mention as making a great step forward in the method of crossing the most treacherous streams flowing through the bottomless delta formation. Four cylinders, 8 feet in diameter, were sunk by the combined methods of jetting, weighting and excavating by hand and pump, all carried on in conjunction with the pneumatic process to a depth of 98 feet below the Gulf level, through river deposits, brush, logs, old foundations, clay, sand and pebbles, within ninety days from the time of starting work. This indeed was a triumph of engineering knowledge and skill which has rendered the construction of bridges across similar streams an easy task in the future.

RIVER AND HARBOR IMPROVEMENT.

Louisiana has the distinction of having had made within her borders the first test on a grand scale in this hemisphere of the efficiency of the jetty system for the removal of bars at the entrance to harbors. The jetties at the mouth of South Pass of the Mississippi River proved such a pronounced success that this method has been adopted almost universally where the conditions seemed to warrant; not only upon the Great Lakes, but at Calcasieu and Sabine Pass in Louisiana, at Galveston, Brazos and several other ports in Texas, at Tampico in Mexico and on the Pacific coast of the United States. The results in Louisiana of this system are certainly equal to the best elsewhere, for at South Pass the depth across the bar was increased from 8 feet to 30 feet, and at Sabine Pass from 6 feet to 25 feet, while the project is now about completed for increasing the depth across Southwest Pass bar from 12 feet to 35 feet.

Again, the general Government is now building a lock between the Mississippi River and the navigable streams to the westward, in Bayou Plaquemine. This will connect the river with prac-

tically tide level at a distance of over 200 miles from the mouth of the river, necessitating an extreme lift of 41 feet. The width of the lock is to be 54 feet, its length 547 feet, the massive walls and bottom being founded on piles with 50 feet penetration in the alluvial deposit of the delta formation. The piling being driven 3 feet between centers over the whole site, the entire weight is expected to be distributed on the whole area by means of a bottom invert. Few inland locks in the world have greater lifts than 25 feet, the greatest being 30 feet, while the famous Avonmouth dock at Bristol, England, built on the orthodox foundation stratum, has an extreme lift of 45 feet.

The success of this gigantic work will be a triumph of engineering skill not without daring, and strike another blow at the pile-driving formulæ so often discredited in this soil. Thus in river and harbor work, Louisiana engineering takes its place well in the lead in magnitude of result and originality of design.

IRRIGATION.

With an annual rainfall of 60 inches, with the greatest river in the world threatening thirty of the fifty-nine parishes of the State with yearly overflow and the remainder watered by innumerable streams, it is not strange that irrigation should have received but scant attention in the past. But rice is fast becoming a world's food cereal, and its cultivation has of late forced the attention of the planter and engineer to the study and construction of irrigation works. The method of a few years ago was, to syphon the water during high stages from the Mississippi and its effluents and to pump it during low stages, on to the adjacent fields, thus limiting the cultivation to the banks of these streams. Now the vast prairies of the western parishes, formerly given up to meager pasturage of cattle, are being flooded by the rice farmer, and 4000 rice harvesting machines are in use to gather 400,000,000 pounds of Louisiana crop. Here, too, the engineer has broken away from tradition and the practice in the Far West, for he has learned that the subsoil of the prairie will hold water; and, instead of expensive flumes of wood with small capacity, he builds great canals, some of them as long as 40 miles, practically on the surface, 30 to 125 feet wide and 4 to 8 feet deep, earthen levees retaining the water, and in some instances transports the products when harvested in barges floated down on the irrigating canal. The lifts from the water courses are as great as 35 feet, and the pumps are among the most improved in design and efficiency. Where the water courses are not available the artesian well is sunk, and some of them are yielding 1000 gallons per minute. Although the work of construction really began as

late as 1897, there are now about 300 miles of canals and at least 75 wells, capable of irrigating together about 300,000 acres of rice fields. With such marvelous progress and rapid construction it seems fair to suppose that much of this work, though done by most competent engineers, has been hastily constructed, with the prime object of delivering the water to the fields in the shortest time and with less regard to the economical design of flume or pump and favorableness of location.

It is therefore probable that the more careful study of flow, seepage and evaporation in the canals, as well as efficiency in location and operation of the pump, which the engineer will give as time permits, will soon begin to check enormous waste and place these hurriedly constructed works on a better paying basis.

The writer has heard of one project which contemplates a canal 55 miles long, 200 feet wide and 4 feet deep, supplied with water lifted 50 feet and retained by earthen levees built on the natural surface. The profits must be stupendous to warrant such construction, with its inevitable immense percentage of waste. But progress in this branch of engineering is making rapid strides, and Louisiana looks forward to becoming queen when rice shall be king.

DRAINAGE.

The exceptionally heavy rainfall, the large area of swamp and level tracts throughout the State, the extensive sea marshes stretching for miles into the interior and the crude methods heretofore prevailing in the drainage of the city, town and plantation open an indefinite prospect of useful and scientific work for the engineer in the near future. In the struggle against overflow, the betterment of the more pressing evils and the cheapness of the higher lands, drainage work in the city and country has been, until recently, postponed until a more convenient season, and in both instances has been confined to the open ditch, supplemented by pumping appliances of which the ancient Egyptians would have been ashamed. But in the last few years there has been an awakening, and the advanced planter is not now content without a complete topographical survey of his lands and has his drains located intelligently, with proper grades and capacities. It is impossible to obtain complete data of the vast amount of private work of this character which has been put in operation of late years, but the State engineers have incidentally done much in this direction, necessitated by the closure of natural low water drains by levee construction.

Moreover, the new constitution of the State empowers large areas to organize into corporate drainage districts; and while one

such has advertised the issuance of over $300,000 of bonds, the proceeds to be applied to a complete and systematic drainage of its territory, others throughout the State are moving towards the same great end.

Among the cities and towns the work of replacing the open gutter with sub-surface drains is moving steadily forward. New Orleans, with the greatest need, as well as the largest area, has begun the construction of a drainage system which is perhaps unique among the cities of the world, in its design and great size of the underground conduits necessary to convey the semi-tropical rainfalls to the pumps which are to lift it to the sea level discharge. With only three of the ultimate eight pumping plants completed, about 15,000 gallons will be lifted from 3 to 10 feet every second during storms by pumps operated from a central electric power plant delivering nearly 2800 kilowatts of energy. In the past two years nearly five miles of masonry conduits, from 5 to 25 feet in width and 5 to 10 feet in depth, have been built, while over 700,000 cubic yards of earth have been excavated in the construction of open canals.

The city of Shreveport has built six miles of sewer mains, while Alexandria and the other towns of the State are beginning to recognize the importance of more efficient and more sightly drainage channels, and are planning their construction. Notably Baton Rouge, which is now constructing a relief canal from its low-lying districts to the swamps, thus providing an ample channel for the run-off of the entire area within its limits.

MUNICIPAL IMPROVEMENTS.

Under this head are classed for convenience the various works of paving, water supply and electric lighting. Only of late has the municipal engineer been recognized as something besides a measurer of lines and a definer of property limits, for it is only recently that the title of the professional adviser of the authorities has been changed from "arpenteur" and later "city surveyor" to that of "city engineer."

Not many years since no town in Louisiana, except this city, could boast of a single paved street, and New Orleans itself, with the exception of six miles of asphalt, was content with the unsanitary plank road, villainous square blocks or barbarous cobblestone pavements upon its business thoroughfares. To-day Shreveport has started her paving with two and a half miles of paved streets already finished, and New Orleans has built in the past eight years, 25 miles of paving of a higher grade than gravel, costing

over $1,500,000, while every town in the State of any pretensions is moving towards the improvement of its principal thoroughfares. Baton Rouge, for instance, has authorized an issue of bonds to the amount of $200,000, $40,000 of which is to be applied to paving.

Where a few years ago the dim gas lamps in the business and chief residence sections of the metropolis, supplemented by the feeble oil lamps in the suburbs and all the smaller towns, served but to accentuate the darkness when the moon defaulted on her contract, now New Orleans is lighted by over 1600 public electric lights; Shreveport has 74 public arc lights; Alexandria is illuminated with 15 1200-candle power arcs and 123 16-candle power incandescents, with provision for increase in the near future; Donaldsonville has 178 street lights; Baton Rouge has 56 arc lights and 1800 incandescents, and all the other towns in the State are making bright their dark places by the dynamo and wire; and the small boy with the large ladder has lost forever his occupation among us.

In the means of water supply all the municipalities of the State are rapidly emancipating themselves from the thraldom of the fickle cistern, for New Orleans has recently provided ample means to furnish an abundant and pure supply; Shreveport pumps 3,500,000 gallons per day through 12 miles of mains; Alexandria has a pumping capacity of 1,000,000 gallons per day from her artesian wells, and is about to inaugurate an air lift system, with reservoirs, to increase the supply and pressure. Baton Rouge, with pumps of 3,000,000 gallons capacity and nine miles of mains, obtains its pressure by means of a 100-foot standpipe, the supply being at present from two artesian wells. Donaldsonville has a plant capacity of 1,500,000 gallons per day, with three miles of mains and a 100-foot standpipe; while at least seventy other towns have water works with an aggregate capacity of about 12,000,000 gallons in twenty-four hours.

Sewerage plants have as yet reached only the planning stage, but in New Orleans their construction is about to begin; and in Alexandria the city engineer, Mr. John W. Sylvestor, has designed a system, for which the money is now available, which involves nine miles of conduit and necessary flush tanks, with pumping appliances for the high water season, and Baton Rouge has provided $55,000 for its system.

STREET RAILWAYS.

Of the street railways we may well be proud as a State, and in this branch the engineer has done most wonderful work since the mule, bob-tail car and flat rail have been abandoned. Of course, it is only in cities of sufficient size, to furnish distances longer than a

lazy man's walking capacity, that there is any need of this kind of conveyance. New Orleans can claim probably the best system of street car lines in the United States. With 180 miles of track, principally girder rails, and over 450 cars operated by electricity, with 14 miles of this laid with 100-pound T rails, creasoted ties and rock ballast, there are few cities which can excel the record.

Shreveport has eight miles in operation, Lake Charles has five miles and Baton Rouge has four miles.

I beg here to state that I am indebted to Mr. F. W. Kane, city engineer of Shreveport; Mr. Ira W. Sylvester, city engineer of Alexandria, and Mr. R. Swart, city engineer of Baton Rouge, and a member of this Society, and Mr. S. L. Carey, of Jennings, for much of the above information.

ELECTRIC WIRE CONDUITS.

Not many years since, when the idea of placing electric wires underground was suggested in order to check the forest growth which was springing up in the streets of our cities, the plea was entered, and vigorously maintained, that the nature of the soil and its saturation with water would forever debar us from the enjoyment of the safety, comfort and sightliness of the underground system, and this in spite of the fact that the Atlantic cables had been working for years in much damper surroundings. But the electrical engineers have come to our rescue, and there are now 30 miles of conduit work completed, which means 240 miles of single duct; and four miles of drain tiles and 870 manholes, the whole costing approximately $850,000. The work is only begun, for the law contemplates the extension of this work throughout the built-up sections. Of course, for many years to come the process of transplanting large forest trees to the suburbs and smaller towns will go on, but the scientific labors of our electrical engineers have demonstrated the feasibility of this construction, and will now bear fruit in the continued extension of the underground system wherever the conditions of the surface require it.

MANUFACTURES AND MODERN BUILDINGS.

Under this heading, in the nature of things, it will be impossible to present any but the most general statistics. Of the manufactures that of sugar refining, of course, ranks first in magnitude, equipment and scientific operation. All of us present to-night can easily remember the building of the first large refinery in this city; now the State is dotted with immense plants located in the cane fields, where once, not long since, the old cast iron open kettle battery sent up its savory fumes through the ventilated roof of the sugar-

house, while the contents of the pots were ladled by tubs at the end of long poles, from the raw juice pot to the strike pot, through five grades of evaporation, burning at every step tons of crystallizable sugar and turning out molasses by the cubic foot per second. The sugar chemist, with his polariscope and high-sounding gibberish about acids and alkalies, was looked upon with unconcealed pity and contempt by the old reliable sugarmaker.

The sugar chemist and high-grade engineer are now indispensable to this great industry; the old bagasse chimney remains only as a monument to past wastefulness, or has become a brick mine; and the bagasse burner under the improved water tube boilers assists in furnishing the power to crush the life-blood out if its quondam companions of the field. The architect and structural engineers are doing their part in this revolution, and many modern buildings and some steel frames now house the high-grade machinery with modern boilers and electric light plants, replacing the single-roof shed covering the old junk and fire flue boilers of the ancient *regime*. The ponderous six or seven-roller mill now crushes the cane to a dry straw, the steam coil and vacuum pan evaporate the water without destroying the power of crystallization, and the centrifugal, with its 2500 revolutions, dries the crystals when formed, and there is now no by-product of Louisiana molasses. There are now 226 great sugar refineries in the State, producing over 320,000 tons of high-grade sugars from the cane per year, and extracting an average of 166 pounds to the ton, instead of the 100 pounds of the good old time; and this exclusive of the four city refineries, which convert throughout the year vast quantities of crude domestic and foreign sugars into the clear crystals of commerce.

Of the other manufactures which the mechanical engineer is placing upon a scientific and paying basis I can only mention in passing such as the great lumber and planing mills, cotton factories, foundries and machine shops, whose wonderful development in Louisiana in the past decade would surprise you could I give the details. Our schools and colleges are, and have been, largely responsible for all of this progress, for they are turning out young men whose knowledge of the fundamental principles and practice of mechanical and chemical engineering as applied to industrial science is to-day rescuing the State from the wasteful and primitive methods of the past.

We can scarcely realize to-day that the modern building, with all its conveniences of plumbing and elevators, its fireproof construction and stable foundations, was begun among us scarcely a

score of years ago, and now the pile foundation and steel frame, the sanitary plumbing and steam or water heating are common to all our larger buildings when designed by architects familiar with our conditions; every year adds to the already large number of modern structures, both in the city and State. Our architects are abreast of the practice of the day, and are designing buildings with all the conveniences and improvements of the age that our climate and soil conditions admit of. As in all other branches of the profession in this State, these conditions are so often and so radically different from those which govern elsewhere that an enforced originality characterizes his work and style of architecture, and he has frequently to depart from all precedent or seek a very rare one, thus taxing his ingenuity and fertility of resource to the utmost.

MINING.

I presume there are few outside the State who have ever heard of a mine in Louisiana, but there are two great and inexhaustible deposits within her borders of prime importance to the world, salt and sulphur. The almost absolute chemical purity of both these deposits entitles them to be termed native. One of the salt mines has been delivering many tons a day for years, and has now reached a depth of 180 feet; and the deposit is said to be 800 feet thick. Except that the location is in the midst of a sea marsh, there is nothing peculiar in the working of these salt mines, but the sulphur mines have thus far defied successful working. The deposit lies about 423 feet below the surface, with intervening strata of clay 160 feet thick, water-bearing sand 179 feet and limestone 84 feet thick. To reach the sulphur it was first attempted by a French engineer to sink a cast iron shaft built of rings about 12½ feet in diameter, cast in France; but the plan proved a total failure. Other methods were later proposed, such as freezing and the pneumatic process, but were rejected as being too expensive. Finally tubes were sunk, as for artesian wells, and superheated steam forced down, which melted the sulphur and forced it to the surface. This method was partially successful, but as the chamber enlarged they have ceased to work. The field is therefore still open to the ingenuity and practical skill of the engineer, and furnishes an additional instance of unusual conditions which beset the path of the profession in this State.

ROAD BUILDING.

There still remains to be mentioned the imperative and unlimited work of road building throughout the State, upon which scarcely anything has yet been done in an intelligent and permanent

manner. With the levee system affording reasonable security against overflow, the resources of the parishes will soon be applied to the betterment of the main country roads, and the construction of great turnpikes. With scarcely any road metal within practical reach the road engineer will find a new and difficult problem before him, but the new constitution has provided a legal way for the inauguration of the work, and he must soon attack it. The time may not be far distant when the automobile will invade the last stronghold of the mule, and supplement the labor of the locomotive and steamer in bearing the products of the soil to the markets of the world.

In conclusion, gentlemen, while apologizing for detaining you by the recital of these dry statistics, I must add that as these startling evidences of engineering activity and achievement unfolded before me in the preparation of this paper the conviction deepened that the grandest possibilities lay before the profession in this section. It is the mission of this Society to foster this growth so well begun; to bring into prominence the part the engineer has had in these marvelous works, and to encourage by its intelligent and approving criticism every triumph of design and execution.

I have sought to emphasize what to me is patent, that in much of the work which confronts the engineer in this State the difficulties and conditions are so different from those in other parts of the world that he is frequently cut off from precedent and left to work out his salvation by his natural ability in the application of fundamental principles, and is obliged to overcome new obstacles by new methods.

It is therefore with pardonable pride that we may as a Society point to these results and justly claim with Æneas, whose energy and skill saved the remnant of Troy's defenders, in his account of himself to Dido, "all of these things we saw, and a great part of them we were."

ADDRESS BEFORE THE THIRTEENTH ANNUAL MEETING OF THE MONTANA SOCIETY OF ENGINEERS.*

By Eugene Carroll, Retiring President.

Mr. President and members of the Montana Society of Engineers: Section 1, Article I of the By-laws of our Society contains these ominous words: "At the annual meeting the President shall present a report containing a statement of the general conditions of the Society and a summary of engineering progress during the preceding year." It is this clause in the Constitution which rises like a specter before the newly-elected President, and remains with him for his full term; until at the opening of the new year he is confronted by the actual reality that he must buckle down to work and try in some way to repay the honor that has been conferred upon him. My immediate predecessors have interpreted this injunction to mean a summary of engineering progress within our own State, and I have followed their example in this address to the best of my ability, having imposed upon many in asking their assistance, as it is the only way I could devise whereby I could intelligently follow out the spirit of the constitution.

The past year has been one of unprecedented prosperity over the whole country, and there is no profession that feels prosperity sooner and to a greater extent than ours. The engineer is the first to suffer from hard times and the first to profit from renewed activity.

Montana has not fallen behind in the universal prosperity of the past year, and the writer has been surprised, in collecting the following notes, at the immense amount of construction during the year 1899 within our State boundaries. It is a pleasure to note that most of this work has been designed and built by members of our Society, and we can justly feel proud of our achievements. In no other branch of the profession has improvement been more marked in our State during the past year than in the mechanical department. The large mining companies of the State have been replacing the old machinery by the most improved and modern appliances. The "hill," as it is designated in Butte, is assuming an entirely changed appearance as compared with that of a few years ago. We can no longer indicate the famous Anaconda Mine to visitors by "those twelve smokestacks on the brow of the hill."

*Manuscript received February 2, 1900.—Secretary, Ass'n of Eng. Socs.

The smokestacks have been replaced by one immense steel chimney. The old familiar, though unsightly, shaft house, with its coat of dull red paint, is rapidly being replaced by the graceful steel gallows frame, with its engine house built alongside of modern fireproof construction, and often with a laudable attempt at architectural beauty.

In collecting the data for this summary the writer has been surprised at the quality and amount of machinery of latest improved pattern which has been installed within the Butte district during the last few years. The following list of the machinery in use at the various mines of the Anaconda Copper Mining Company will no doubt be interesting to many of you:

Anaconda Mine. One double-deck 30 by 72 Poppet valve hoisting engine, built by the Union Iron Works. One cross compound Ingersoll air compressor, steam cylinders 24 and 44 by 48. Air cylinder 24¼ by 48. Boiler plant—six 200-horse power marine boilers.

Never Sweat Mine. One double cross compound vertical Corliss hoisting engine, steam cylinders 26 and 46 by 72, built by the Union Iron Works. Two cross compound Ingersoll air compressors, steam cylinders 30 and 56 by 60, air cylinders 30¼ by 60. Boiler plant—seven 250-horse power Berry boilers.

St. Lawrence Mine. One double 30 by 72 Poppet valve hoisting engine, built by the Union Iron Works. Three 500-gallon Corliss pumps, air cylinders 17 and 28 by 30, built by the Dickson Manufacturing Company. One 500-gallon Reidler pump, steam cylinders 15 and 25 by 30. Boiler plant—five 250-horse power Berry boilers.

High Ore Mine. One double 30 by 72 Poppet valve hoisting engine, built by the Union Iron Works. One Ingersoll-Sargeant air compressor, steam cylinders 26 and 40 by 60, air cylinders 30¼ by 60. One Ingersoll-Sargeant air compressor, steam cylinders 30 and 50 by 60, air cylinders 30¼ by 60. Three 500-gallon Dickson pumps, air cylinders 17 and 28 by 30. Boiler plant—1920 horse power.

Bell Mine. One double 20 by 48 Corliss hoisting engine, built by the Chicago Iron Works. One Ingersoll-Sargeant air compressor, steam cylinders 24 and 44 by 48, air cylinders 24¼ by 28. Boiler plant—1420 horse power.

Diamond Mine. One double 30 by 72 Corliss hoisting engine, built by the Risdon Iron Works.

Green Mountain Mine. One double 28 by 72 Corliss hoisting engine, built by the Webster, Camp & Lane Company. One Inger-

soll-Sargeant air compressor, steam cylinders 24 and 44 by 48, air cylinders $24\frac{1}{4}$ by 48. One Reidler air compressor, steam cylinders 30 and 50 by 48, air cylinders 29 and 50 by 48. Boiler plant—1560 horse power.

Mountain Con Mine. One double cross compound vertical Corliss hoisting engine, steam cylinders 26 and 46 by 72, built by the Union Iron Works. One Ingersoll-Sargeant air compressor, steam cylinders 24 and 44 by 48, air cylinder $24\frac{1}{4}$ by 48. One Ingersoll-Sargeant air compressor, steam cylinders 22 and 40 by 60, air cylinder $22\frac{1}{3}$ by 60. Boiler plant—1280 horse power.

Mountain Con Mine No. 2. One double 20 by 48 Corliss hoisting engine, built by the Webster, Camp & Lane Company.

The foregoing illustrates the class of machinery now being installed in our large mining properties, and I thought not out of place in a paper of this character. To the chronic alarmist, who is continually prophesying that the mines are pinching out and that the metropolis of our State has but a few years of municipal life ahead of it, I commend the above list of machinery installed and being installed at the various mining properties in that district as an object lesson worthy of study. With the diamond drill the miner of to-day can look into the bowels of the earth, and it certainly does not look as if the owners of properties in the Butte district have found nothing by so doing.

ANACONDA MINING COMPANY.

The principal improvements at the Anaconda Copper Mining Company's properties which can be credited to the year 1899 are as follows:

Anaconda Mine. New boiler plant, consisting of six 9 feet diameter by 22 feet long marine boilers, built for working pressure of 170 pounds per square inch. The building is of steel and brick, the chimney is of steel, 8 feet 9 inches in diameter and 125 feet in height, and self-supporting.

St. Lawrence Mine. Three new cross compound Corliss pumps have replaced the old Knowles pumps.

Never Sweat Mine. One cross compound Corliss compressor has been installed, and one more is under construction.

High Ore Mine. This plant has been entirely rebuilt with the exception of one end of the boiler plant. The improvements consist of one new steel gallows frame 100 feet in height, one steel engine house, one steel compressor building, two large Corliss air compressors, one double 30 by 72 hoisting engine, six marine boilers, one 8 feet 9 inches self-supporting steel chimney 125 feet

in height, one sawmill, one rope house, one machine shop, new ore bins, and new cross compound Corliss pumps have replaced the old Knowles pumps; also one double 10 by 16 geared hoist and cage for pump shaft.

Diamond and Bell Mines. One 100-foot steel gallows frame, one steel engine house, one double 30 by 72 hoist and four new marine boilers.

All the mines mentioned are provided with 9 and 10-ton skips for hoisting the ore, and it has been definitely settled that skips can be hung either above or below the double-deck cage without any inconvenience.

The ore is either dumped direct into the ore bins at the railroad track, or hauled there from the skip bins by air locomotives and 5-ton cars.

BOSTON AND MONTANA AND BUTTE AND BOSTON MINING COMPANIES.

I am indebted to Mr. C. H. Repath, member Montana Society of Engineers, for the following description of the improvements at the Boston and Montana and Butte and Boston properties during the past year:

"The most important work completed this year, but commenced in the year previous, was the completion of the converter plant at the Butte and Boston smelter, together with the power house and boiler plant. The boiler plant consists of five Evans locomotive fire-box boilers, capable of carrying 150 pounds pressure, and having a heating surface of 2100 square feet each. The plant is equipped with coal bins for the storage of coal, and coal-handling apparatus for receiving the coal from the cars and storing it into the bins. Coal is brought to the plant by dump cars, and these cars dump the coal into a hopper under the railroad track. From this hopper a Jeffry coal elevator elevates the coal to a sufficient height and distributes it into the coal storage bins. There are openings in these bins directly opposite each boiler. The ashes from the boilers drop from the grates into pockets under the boilers, and from thence are loaded into a car that runs in a tunnel underneath the floor of the boiler house. At the end of this tunnel or cellar there is a platform elevator that takes the car up about 20 feet. From thence it is run on to a trestle. This provides an ash dump of about 20 feet high.

"The smoke from these boilers enters a large underground flue, which communicates with a large stack that is 7 feet in diameter and 156 feet high. The boiler house is a brick building with steel posts, rafters and composition roof.

"*Power Plant.* We have completed this year a new power house 92 feet by 92 feet. In this power house we have placed a power engine having 900 maximum horse power. This engine furnishes power for the concentrator, for a power pump and also for about 500 horse power of electric machinery for lighting our mines, and for furnishing electric power for the smelter. In this power house is also located a large blowing engine for furnishing air for our converter plant. The power house is a fireproof building, and is equipped with three cranes for handling the machinery. There is also installed a Worthington power pump having a maximum capacity of 300 gallons per minute. The pump is driven from the main shaft of the concentrator. This pump gets its water from a large shallow reservoir made by putting a dam in Silver Bow Creek. This has been built during the last year. From this pond the water passes through a large tunnel that ends near the power house. This tunnel is 6 feet wide and 8 feet high in the clear and 350 feet long. The pump cylinders are placed in a large well, and the power end of the pump is situated above the water cylinders.

"*Converter Plant.* The converter plant was mostly built in the year of 1899, but was started in 1898. The building is a steel building, equipped with a 40-ton crane and all necessary apparatus for converting copper matte. There are two complete stands of converters and four extra converter bowls. Air for blowing these converters is furnished by the blowing engine above mentioned, the air being conveyed in a pipe located in a tunnel which extends from the converter plant to the power house. The type of converters used is what is known as the barrel converters.

"*Concentrator Plant.* At our concentrator we have made an extensive addition, known as the slime table addition, in which has been placed eight double-decked Evans slime tables. We have also erected what is known as the tailings elevator building, for elevating tailings made by the treating of ores in our concentrator. They are capable of elevating 2000 gallons of water per minute with the tailings from our mill. It had become necessary to elevate our tailings high enough so that the trestle work which supported the tailings launder would clear the street railway and the Northern Pacific tracks. The trestle work that carries this tailings launder is about 900 feet long, and in some places is about 50 feet high.

"*Smelter.* We have also installed several electric motors. These are the latest type Westinghouse and General Electric three-phase induction motors. The power for operating these motors is supplied by a three-phase Westinghouse generator situated in our power house. This generator has a capacity of 180 K. W. The

tramming of our slag is also done by an electric locomotive, which has been recently installed.

"At the mines of both the Butte and Boston and the Boston and Montana there have been only minor improvements made in the way of machinery. At both the Mountain View and the Leonard Mines of the Boston and Montana Company we are erecting steel gallows frames. These are 94 feet high over all. The method of handling and tramming the ore after it reaches the surface of these mines will be done hereafter by horses instead of by men as at present. In front of the new gallows frames bins have been erected, the tops of which are about 24 feet above the collars of the shafts, thus giving us sufficient height to store the ore and also load it into cars holding about five tons each. Horses will take these cars out tc the railway bins, which are situated several hundred feet distant.

"At Great Falls the company has built and put into successful operation large blast reverberatory furnaces. The former, under favorable conditions, have smelted over 500 tons of material per day for each furnace, and the latter nearly 200 tons. A new calcining or roasting plant has been built, each furnace having a daily capacity of 35 tons, and using no fuel. The roaster is of the McDougall type, as patented in England in 1891, with some important improvements."

GREAT NORTHERN MINING AND DEVELOPING COMPANY.

I am indebted to Mr. E. W. King, member Montana Society of Engineers, for the following description of the work done during the past year by the Great Northern Mining and Development Company at Gilt Edge, Montana:

"A new plant has been built at a cost of about $75,000 for the treating of ore by the cyanide process. The plant was built during the winter of 1898-99, and the extremely hard weather made the construction of it very slow, as over one million pounds of machinery had to be freighted by wagon from Fort Benton and Armington to the mines, a distance of about 120 miles and over a range of mountains. The present capacity of the mill is 140 tons of ore per day, and this will probably be increased to 200 tons per day during the coming summer. The ore is crushed as it comes from the mine by a No. 5 Gates crusher; from there it passes through an E. P. Allis drier, thence through two sets of 16 by 30-inch Gates rolls, and from there to a large storage bin, from which it is discharged into the leaching tanks by a 2-ton car run by a cable. There are six leaching tanks, each 28 feet diameter by 3 feet high, with the usual solution, settling, sump and wash water tanks. The

mill is operating very satisfactorily, and the mining and milling is done cheaply enough so that ore assaying $2.50 per ton can be worked at a profit."

MONTANA ORE PURCHASING COMPANY.

Mr. G. H. Robinson, member Montana Society of Engineers, has kindly furnished me with the following, showing the improvements made by the Montana Ore Purchasing Company during the year 1899:

"The smelting plant consisted of four reverberatory smelting furnaces at the beginning of the year, with a capacity of 180 to 200 tons of ore per day. These have been increased by the addition of two new ones of larger capacity, and the roasting plant has been increased by the addition of forty-five circular roasters, having a capacity of about 6 tons each per day. Two additional blast furnaces have been added to the plant, and will be blown in in the near future. These furnaces will have a capacity of 250 tons each daily. The entire power plant has been overhauled, and enlarged by the addition of a compound condensing engine of 300 horse power for operating the smelter plant. A new blowing machine of large capacity, especially built for operation by steam or electricity, capable of supplying air to eight stands of copper converters, has been added, the converting department having been doubled during the year; while the boiler plant has been increased by the addition of 1000 horse power in Stirling water tube high-pressure boilers.

"Generally speaking, the plant has been rebuilt, and capacity of plant increased from 1,000,000 pounds of copper per month to 4,000,000 during the same period, and it brings this plant up to the dignity of one of the large copper smelting plants of the district and country.

"The increase of reduction plant has made it necessary for the company to correspondingly improve and increase the capacity of its mining plant."

At the Rarus, owned by the Montana Ore Purchasing Company, the No. 1 shaft has been abandoned, and the No. 2 shaft has been equipped with a powerful first motion engine, capable of hoisting from a depth of 2100 feet. A duplex compound 20 by 60 Rand air compressor, capable of supplying air to fifty machine drills, built for operation by steam or electricity, is being installed, and an entirely new plant of high-pressure boilers, rated at 900 horse power, is under construction at a convenient point to permit the large coal dumps recently adopted by the coal companies and railroads to discharge into the coal pit of the boiler plant. A new

pumping plant is also under construction, suitable for deep mining, the pumps being the compound condensing plunger type, with a maximum lift of 1200 feet.

The Heinze syndicate, who own the Montana Ore Purchasing Company, have also installed a new boiler plant of 700 horse power at its Nipper Mine, and a compressor plant with 30 drills capacity. A new double first motion 20 by 60 engine is also under contract for this property. The mining plants at its Schweizer, L. E. R., Corra and Minnie Healy mines are as yet only heavy prospecting plants, and will be replaced by heavy mining plants during the present year.

Not wishing to confine this summary entirely to mining, though probably the largest part of our members are connected with this industry, the writer has selected the above companies to illustrate the progress of engineering within our State under this head. The underground development would be interesting, but for reasons undoubtedly good it is impossible to obtain any information upon that subject, and we can only surmise that the development work has kept pace with the surface improvements.

IRRIGATION.

During the year 1899 there has been no unusual activity in irrigation projects throughout the State, though the following notes show that we can with satisfaction "report progress and ask for more time."

Through the investigations and energy of the State Arid Land Grant Commission, as well as through private enterprise, we may hope in the near future to see many barren wastes transformed into thriving ranches, increasing our population and prosperity. Every acre of ground redeemed by irrigation is a standing advertisement to the world, and will bring a class of immigration which will benefit the State in every particular. The farmer is always a growler, and never exactly satisfied with conditions, but there is no more independent and valuable immigrant to induce to become a citizen of our State.

I am indebted to Mr. Donald Bradford, member Montana Society of Engineers, for the following:

"The State Arid Land Grant Commission has done considerable engineering on a line of canal near the town of Bridger, in Carbon County, Montana. The canal will be 8½ miles long, 15 feet wide on the bottom and will carry 5 feet depth of water. It is proposed to irrigate 12,000 acres of very fine bench land. Work should be completed in the spring.

"We have a number of engineers in the field in Northern Montana on some preliminary work, preparatory to the segregation of lands and the construction of a canal. The engineers are not ready to report as yet, so I cannot give you any information on that point, but will be glad to do so when information is available.

"We also have a number of engineers in district No. 2, in Sweet Grass County, who are now preparing plans and specifications for a canal for the reclamation of 50,360 acres of land. The contract has been let, and work will begin this winter on the headworks."

Mr. E. C. Kinney, member Montana Society of Engineers, writes as follows concerning the enterprise of which he is manager:

"The West Gallatin Irrigation Company have now about 60 miles of main canal, with probably 20 miles more of laterals. We carried about 6000 inches of water at the head of the canal, and watered crops on 3800 acres. The loss from seepage on so long a run is very great, and has annoyed us greatly. It is proposed next year to make some tests and locate if possible the trouble, with a view to correcting it.

"We have during the last year nearly completed 18 miles of new main line canal, for the purpose of supplying water to the lower end of our present canal. In the original construction of the canal, after the line had been constructed on grade for 32 miles, there was put in a drop of 300 feet; then the line was carried on for more than 20 miles. We have always found trouble in supplying this lower part. We found that by building a cut-off of 18 miles from the river we could strike the lower part of the canal at a point 35 miles from the head by the old line. It was judged best to build the new line rather than to try to enlarge the old canal, especially as it had been developed that there was plenty of land above the new junction point to use all the water that could be carried in the old canal.

"In the construction of the new canal we have introduced some new methods in the way of shortening the line and making it more permanent. At one point we used a thorough cut 900 feet long and 40 feet deep at the deepest place, rather than build 6½ miles of canal over very bad ground. At three other points we used the Allen patent wood stave pipe to cross deep ravines, rather than to build long distances around over bad ground. These pipes are respectively 660 feet of 44-inch pipe with a drop of 12 feet, 2000 feet of 46-inch pipe with a drop of 12 feet and a hydraulic head of 114 feet, a third pipe 1180 feet long, 34 inches diameter and a drop of 28 feet, and a hydraulic head of about 60 feet. Otherwise I think there is nothing out of the usual run of canals."

Mr. A. E. Cumming, member Montana Society of Engineers, writes from Fort Belknap that the construction work contemplated for the year 1899, under his supervision, on the Fort Belknap irrigation system has been delayed from various reasons, and that only a small amount of preliminary work has been done, consisting principally of the making of a contour map of about 3000 acres of land to be irrigated by the proposed system. Mr. Page in his address last year quite fully described this project, and we hope at some future time to hear from Mr. Cumming on the construction, with Indian labor to do the work.

MUNICIPAL WORK.

The population of our State is increasing fast, and each year sees laudable efforts by our citizens to beautify and improve their cities. In many of them we find the streets being paved, and improved laws made whereby the buildings are constructed with more care and, incidentally, with more architectural taste. Our private residences, schoolhouses and public buildings are not designed by carpenters and built with straight lines, mere unsightly masses of brick or wood, as was the case a few years ago. More and more each year do we see a desire for the beautiful, which shows that we are gradually outgrowing that sentiment of the past that we are only sojourners here. We begin to realize that Montana is our home, and that we are not residents of an undesirable State, Grover Cleveland to the contrary notwithstanding. We feel that Montana is our home, and we desire to make that home a credit to ourselves. In no way is this feeling more positively demonstrated than in the great strides our cities have made in the past few years in municipal improvements. In the street improvements, sewer extensions, water works construction and school buildings of the past year we see a desire to do permanent work, and an indication that we are no longer mining camps, but growing cities, in which the health and comfort of the inhabitants demand some consideration.

In Butte there has been laid during the past year 10,705 square yards of granite block pavements, with 3238 lineal feet of permanent curb. In addition to this nearly $25,000 have been expended in extension of permanent storm and sanitary sewers. 11,270 lineal feet of wooden sidewalks have been laid in addition to the permanent sidewalks laid in connection with the permanent paving. Over $35,000 have been expended in repairs and extensions of unpaved streets, and plans are now being formulated to extend the street paving still more during 1900. The extension of the water

plant is now being constructed, whereby the source of supply will be the Big Hole River, and it is hoped and expected that the water question of Butte will thereby be permanently settled. This extension, of which the writer is chief engineer, is now about half done, and it is to be hoped that by the next annual meeting of our Society the new works will be in operation. The street car system has been extended, and many permanent improvements made in its plant. Mr. Blackford, member Montana Society of Engineers, says their extension to the Columbia Gardens during 1899 was the principal construction work. The old line, which was laid with light rails upon a grade in some places of 7 4-10 per cent., was replaced by a double track laid upon a roadbed with a 6 per cent. maximum grade. The new track was laid with 52-pound rails, and the total cost amounted to $28,500. This branch, as well as the remarkable extension described by Mr. Blackford in a paper before the Society during 1898, have been successfully operated during the past year with no serious accidents.

Mr. McDonald, member Montana Society of Engineers, city engineer of Anaconda, writes that they have built during 1899 3700 feet of lateral sewers, and graded about two miles of street, besides the regular work of maintenance. It will not be long before Anaconda will have to get in line with the other cities and start permanent street improvements.

There are many matters under the head of municipal engineering which would be of benefit to the Society and others to have brought up for discussion. Mr. Swearingen has called my attention to some defects in our laws in relation to municipal improvements, but lack of time and space prevents their discussion at this time. It is to be hoped, however, that he will bring the subject before the Society at some future time, for it is a subject in which every taxpayer is interested, as well as members of the Society. The question of the proper material for permanent street paving is another important subject which would be interesting and instructive for the Society to take up. It will not be many years before several other cities in the State, besides such as are now making improvements, will have to grapple the subject of street paving. The writer believes that granite blocks should be used sparingly, and believes if some encouragement were offered that a clay could be found in Montana from which a first-class paving brick could be made, and a cheaper and better pavement result. The noise from granite block pavements is the most objectionable feature, and as the paved streets extend beyond the interior business section the evil will be more fully realized. During a recent visit in the East

the writer saw granite blocks being removed and replaced with asphalt, although the blocks were in first-class condition. During the year we have had one able paper on this subject by Mr. Blackford, and it would be of great value to us all if the matter could be further discussed. Discussion of such matters by this Society should have weight with taxpayers and city officials, and if we succeed in obtaining better and more satisfactory work in any one case it will be a satisfaction and reward for the trouble.

RAILROADS.

Railroad construction during 1899 has been active all over the United States, and promises to be more so in Montana during 1900. Owing to the fact that the railroad companies do not divide their statistics by State lines, the writer feels doubly grateful for the following notes, as they represent considerable trouble to produce them.

Mr. E. H. McHenry, honorary member of our Society, has kindly furnished the following information concerning the work in Montana by the Northern Pacific Railway Company:

"*Construction.* During the present year the Clarks Fork branch, 19.44 miles in length, and Gaylord branch, 22.2 miles in length, were completed. These branches were begun the previous year. The former was constructed from its junction with the Rocky Fork branch, near Rockvale, to Gebo and Bridger for the purpose of serving the coal mines along the Clark Fork Valley. The latter was constructed from the Parrot Smelter to Twin Bridges.

"*Improvements and Betterments, Constructed Lines.* A great number of timber bridges were replaced by embankments and steel bridges, but the statistics for Montana cannot be segregated. Our old steel rail of 56 pounds section was replaced by new rail of 72 pounds section, as follows: Yellowstone division, 40.28 miles; Montana division, 29.16 miles; Rocky Mountain division, 19.1 miles. Nearly all of this was in the State of Montana.

"Track was ballasted on the various divisions as follows: Yellowstone division, 59.4 miles; Montana division, 61.4 miles; Rocky Mountain division, 51.3 miles. In all cases banks were widened, sags filled and spiral easement curves provided at curve ends.

"Grades were reduced along the Yellowstone Valley and between Bozeman and Helena and between Garrison and Avon, the details of which are given in the annual report.

"The permanent lining of the Big Horn Tunnel with concrete and brick was completed. The total length of lining was 1068

lineal feet, requiring 4043 cubic yards of concrete. The work of permanently relining the Iron Ridge Tunnel is now in progress. The Avon Tunnel, in the Hell Gate Valley, is now being taken out as an open cut.

"Extensive terminal improvements were made at Livingston, Butte and Missoula. Interlocking plants were provided at the crossing of the Montana Central Railway at Butte.

"Permanent steel structures have been authorized at various points on the main line at twelve different stream crossings, the work on which is now in progress."

Mr. J. C. Patterson, member Montana Society of Engineers, gives the following summary of work in Montana by the Great Northern Railway during 1899:

"Havre to Great Falls—Bridge No. 608, 110 feet long, replaced with 48-foot steel girders on masonry; bridge No. 616, 81 feet long, replaced with 24-foot steel girders on masonry; bridge No. 621, 80 feet long, replaced with 24-foot steel girders on masonry; bridge No. 622, 94 feet long, replaced with 24-foot steel girders on masonry; bridge No. 749, 80 feet long, replaced with 18-foot steel girders on masonry, making 445 feet of pile and trestle bridge replaced with 138 feet of steel girders on masonry foundations, balance of the structures being filled.

"Great Falls to Helena—Bridge No. 23, 378 feet, replaced with one 200-foot through truss and three 45-foot through girders on masonry.

"Helena to Butte—Bridge No. 82, 90 feet long, replaced with 60-foot steel deck; bridge No. 83, 133 feet long, replaced with 60-foot steel deck; bridge No. 85, 86 feet long, replaced with 48-foot through plate girder; bridge No. 86, 82 feet long, replaced with 60-foot through plate girder; bridge No. 90, 70 feet long, replaced with 60-foot through plate girder; bridge No. 121, 105 feet long, replaced with 36-foot through plate girder, making 566 feet of bridges replaced with 324 feet of steel bridging on masonry foundations.

"Great Falls to Neihart—Bridges 180, 186, 187, 188, 189, or a total of 1243 feet of bridging completely filled, requiring 171,352 cubic yards of filling, which was done by steam shovel and work trains.

"Relaying during 1899—Between Wolf Creek and Silver and Northern Pacific crossing and Helena 25 miles were relayed, taking up 60 and 68-pound steel and putting in 77½-pound rail.

"Between Woodville and Butte about 8 miles were relayed, taking out 75-pound steel and putting in 77½-pound."

I attach hereto a description of the work of the change of line between Verona Junction and Marias Junction, on the Great Falls line, between Havre and Great Falls, as written by Mr. E. R. McNeill, engineer in charge of the work:

"The Verona to Marias change of line on the Great Falls-Havre division has involved the construction of 24 8-10 miles of new line, leaving the present constructed line about 7 miles west of Big Sandy, and connecting with it again about one-quarter mile west of the Teton River crossing. The object of this change is to reduce the 1 per cent. eastbound and westbound gradients to 0.5 per cent. eastbound and 0.4 per cent. westbound, and to reduce the maximum degree of curvature from 6° to 4°. The grades on the new line are compensated for curvature, while the 1 per cent. grade on the constructed line is not compensated. The constructed line between the termini of the new line runs over a rolling prairie country. It was light prairie construction without any difficult engineering features, while the new line, which does not depart from it more than six miles at any point, traverses a rough and precipitous route, involving a considerable amount of difficult construction work. After leaving the point on the constructed line seven miles west of Big Sandy, the new line follows the east bank of Coal Bank Coulee for a distance of five miles, to a point near its junction with the Missouri River, when the coulee is crossed with a steel trestle 832 feet long and 90 feet high, made up of 32 and 64-foot girders carried by steel towers, which are supported upon masonry pedestals. From this bridge the line follows along the north bank of the Missouri River for a distance of 17 miles. About six miles of this distance is along perpendicular cut banks of clay and shale, which extend to a height of from 100 to 150 feet above low water. Along these cut bank sections considerable difficulty was encountered in laying out the work for the contractors, and in many cases cross-sectioning has been resorted to three separate times to correctly determine the cubic contents of material moved. Before the taking out of the roadbed prism was undertaken on the cut bank sections, holes were drilled along the margin of the perpendicular bluffs. These holes were generally about 25 feet deep, and were heavily loaded with black powder, a line of them being fired simultaneously by battery. In this manner the bluffs were brought to a uniform slope, and the line was retraced and the roadbed cross-sectioned. About 125,000 cubic yards of material was moved by means of an hydraulic, the operation being similar to hydraulic mining, except instead of getting the pressure under a gravity head it was secured by means of a large pump and boiler mounted upon a barge in the

Missouri River, the water being pumped direct from the river and forced through a pipe line and nozzle against the bluffs. The material so moved was washed into the river, as it was not required for embankment at that particular point. If necessary, however, material can be carried into embankment by fluming. Loam, sand and gravel can be moved by this method at an exceedingly low cost per cubic yard. Clay and shale, which first are required to be blasted, and afterwards break in large blocks, are not worked so satisfactorily. At the west end of this change of line the Marias River is crossed with a 550-foot steel truss bridge, consisting of two 200 and one 150-foot spans, supported on first-class masonry piers. The piers have pile foundations with steel rail grillage, carrying 4 feet depth of concrete, upon which the masonry is built. The stone used in piers is Great Falls sandstone. About seven miles of line and adjacent river bank will require riprapping to a height of from 5 to 15 feet, requiring about 50,000 cubic yards of riprap. About 1,500,000 cubic yards of loam, hard pan, shale and rock will be moved. 800,000 F. B. M. timber has been used in culverts. Pile and trestle bridges 520,000 F. B. M., piling 28,700 lineal feet. Two steel and masonry bridges as hereinbefore described."

In considering the magnitude of this new work, and the resultant abandonment of the present operated line, the doubt naturally arises as to the wisdom of the undertaking, but when it is considered that the 300 class locomotive, which is rated at 620 tons train capacity over the present operated line, will be able to haul 1265 tons over the new line, and other classes of locomotives at about the same increased ratio, one is readily convinced that the investment is a good one.

The work has been done under the direction of Mr. John C. Patterson, resident engineer, Mr. E. R. McNeill having been engineer in charge of the work.

POWER DEVELOPMENT.

The large and increasing demand for electricity for power and other purposes has stimulated the development of water power in our State during the past few years, and as soon as the question of the practicability of long distance transmission is thoroughly settled the writer expects to see many more such enterprises constructed throughout the state. During the past year the Montana Power Company, of Butte, have successfully overcome their many difficulties, and are at present operating their plant and delivering power in Butte. This makes three large water power plants in successful operation within the State, and there are several others in contemplation which the year 1900 may see actual facts.

SOCIETY AFFAIRS.

The reports of the Secretary and Treasurer show the Society to be in a healthy condition. The large number of applications before this meeting is eminently satisfactory, and the writer hopes that our membership may continue to increase. For details concerning these matters you are referred to the reports of officers. At present we have a membership of one hundred and forty-two, with nine applications before the Society.

The year 1900 will mark an era in the history of the Montana Society of Engineers, in that the headquarters have been removed from Helena to Butte. This step was first considered advisable because there are a large number of engineers whose headquarters are in Butte, and a correspondingly small number in Helena. It is hoped that a greater interest can be promoted in the Society by holding the monthly meetings at a point where a majority of the members of the Society reside. It is also hoped that many more engineers can be induced to join the Society.

At this time we must not overlook the splendid record of the engineers of Helena in the past work of our Society. We have now a membership sufficient to warrant success and continued prosperity, but in the days when the Society was in its infancy and Montana was almost unknown a few enthusiastic and energetic engineers of Helena, by their interest and indefatigable efforts, kept the Montana Society of Engineers alive, and to them, more than anything else, do we owe our present prosperous condition.

The one serious drawback to the professional benefit the Society should be to each member is the lack of professional papers during the year. It is not only a benefit to the Society at large to hear the experiences of others in engineering subjects, but it is often of greater benefit to the writer, in that the discussion provoked by his paper will often introduce new ideas of value to himself in future work. If members who have not the time to devote to the preparation of a paper would talk from their notes, not with the idea of publishing, many interesting and instructive meetings could be held during the year. The Society should have at least one paper at every monthly meeting, and if each one of you will resolve to do something for the benefit of our Society I am sure there is no better way than to resolve to give us your views or experience on some engineering topic, let it be ever so brief.

Through the efforts of our committee of last year, ably assisted by the Hon. E. H. Wilson, member Montana Society of Engineers, House Bill No. 29, an "Act establishing a standard of measurement for water," was passed by the last Legislature. This is cer-

tainly encouraging, and by confining our efforts to matters wholly within our province as engineers we may hope for further success in reforming present laws.

Contrary to expectations, the compiling of this report has been a pleasure; the writer fears more of a pleasure to himself in writing than to the Society in listening to a dry summary, without sufficient detail to make it interesting from an engineering standpoint and lacking in literary merit. And yet in preparing the notes he has been confronted with the fact that our State has advanced to such large proportions, with so many diversified interests, that it would have required all his energy to do justice to any one subject. It is possible that we would obtain more interesting matter were the retiring President allowed to select his own subject and treat it as he saw fit, instead of confining him to a summary of engineering progress. However, the writer has used his best endeavors to obey the Constitution as he interprets it, and, in conclusion, wishes to congratulate the Society upon its past success and hopes it may have continued prosperity in the future. As a member he pledges himself to do all in his power at all times to promote its interests.

OBITUARY.

Samuel Nott.

By L. B. Bidwell and Edward Sawyer, Committee of the Boston Society of Civil Engineers.

[Read February 21, 1900.]

Samuel Nott, C.E., born in Bombay, India, April 28, 1815, was a charter member of this Society, its Secretary from March 6, 1849, to August 7, 1874, and an honorary member from May 20, 1891, till his death, at Hartford, Conn., October 1, 1899. His last meeting with the Society was at the commemoration of its fiftieth anniversary, in November, 1898.

He was a son of Roxana (Peck) and Rev. Samuel Nott. His paternal grandfather was also a clergyman, of the same name, who was minister to the Congregational Church in Franklin, Conn., for seventy years. From an interesting notice of him, in the *Connecticut Quarterly*, we learn that when he was studying for the ministry his health was so poor that it seemed doubtful whether he would be able to take charge of a church, yet he developed into a man of strong character, large ability and great physical endurance, which carried him through some very trying experiences,—walking, driving, etc., in the severest storms,—in fulfillment of professional engagements, even as late as his 94th year, and he lived 98 years.

In the next generation, the father of the subject of this sketch was one of the five theological students (Hall, Judson, Newell, Nott and Rice) whose desire to go out as missionaries was the occasion of the organization of the American Society for Foreign Missions in 1810. Four of them went to India, with their wives, in 1812 (as soon as the finances permitted). Hall and Nott settled in Bombay. The latter soon became ill and it seemed necessary for him to return home in 1816. He sailed with his wife and infant son, on the ship "General Stewart." Putting in at St. Helena, they heard for the first time that Napoleon had been defeated at Waterloo, and was then in detention on that island.

Mr. Nott regained his health and established a private school, which he maintained for many years. After a time, he settled at Wareham, Mass., and preached there nearly to the end of his life of 92 years.

The late Samuel Nott, C.E., is said to have had many of the characteristics of these well-endowed ancestors. He began in

1833, as a rodman under Col. Fessenden and his assistant, Edward Schenk, on the construction of the railroad from Boston to West Newton. During his service there, of more than a year, he made it his rule when not in the field to keep himself in sight at the head office and be as generally useful as possible, often being sent on long walks by the chief.

Other men of his grade jeered at him for this, and made it their rule to shirk and keep out of sight as much as possible. He rapidly acquired skill, and became well and favorably known to his chief.

Soon after this engagement, he went with Col. Fessenden to begin the engineering work for the Eastern Railroad, and he continued on this road, and its connections through to Portland, with little if any interruption, for about ten years. The building of the first part, from East Boston to Salem, was put under three division engineers, and Mr. Nott had charge of the middle division, with his office at Lynn. This part, from East Boston to Salem, was opened for business on August 27, 1838.

The same engineers were then transferred to the next three divisions, from Salem to Newburyport. Mr. Nott had charge of the first of them, including the Salem tunnel, which was built in 1839. His assistant in immediate charge of the tunnel work was Francis Chase, C.E., who is now living in Salem, in reasonable enjoyment of well-earned leisure. We are indebted to him for much information in regard to this line through to Portland.

For building the next extension,—to Portsmouth, including the Eastern Railroad in New Hampshire,—the same engineers were assigned. In the same way, Mr. Nott had the first division, including the Newburyport bridge across Merrimac River, a wide and deep tidal stream at this place. Plans and schedules of materials were made for it by Col. Fessenden, but were changed somewhat, as a result of Mr. Nott's later investigations. The old highway bridge was strengthened by additional piles and caps, and a second story was built upon it to carry the railroad on its upper deck. This comparatively cheap structure, begun in July, 1841, answered its purpose till about 1867. Then a more substantial bridge was built, a short distance up stream, under direction of T. Willis Pratt. This had piers of cut stone (built with the use of a diving bell) and good timber trusses, which were replaced by the present iron ones in 1886.

Col. Fessenden's connection with the line ceased with the completion of the road to Portsmouth, but preparations for extension, including the Portland, Saco and Portsmouth Railroad, were be-

gun before that. The three division engineers from the Eastern road were put in charge as chief engineers, each on a division, but each under instructions to consult with the others as to his own work and theirs.

Mr. Nott had the first division, from Portsmouth to South Berwick. In November, 1841, he reported to the President of the Eastern road as to the probable cost of this part of the line. This included the construction of a bridge across the Piscataqua River, a tidal stream with a main channel width of nearly 1700 feet and a maximum water depth of some 60 or 70 feet.

He made careful and elaborate studies for this bridge, including novel schemes for doing the submarine work for stone piers. In 1842 he reported results as to plans and costs. Money was not abundant in those days, and economy of first cost, down about to the lower limit of practicality, was imperative. Accordingly, a comparatively cheap scheme was adopted. The old pile bridge for the highway was widened, straightened and strengthened to fit it for carrying the track also, by use of many new piles, some of them spliced to lengths of nearly 100 feet. The piers, so built and strengthened, were spaced at short, irregular intervals, where the piles would drive best. The trusses were of several different lengths and styles, but all short and light. This work has answered its purpose, down to the present time, under good care and with much introduction of new timber as needed; and it is now carrying the heavy traffic which has grown up on this important main line.

Soon after the completion of his work on the Portland, Saco and Portsmouth Railroad, about 1844, Mr. Nott opened an office at No. 34 State street, Boston, for general engineering practice. In May, 1845, in collaboration with Waldo Higginson, he made a survey for a railroad from the northern boundary of Massachusetts, at Townsend, toward Peterboro, N. H. In December, 1845, he made surveys and estimates for different railroad lines between Lowell and North Andover; and the building of the Lowell and Lawrence Railroad followed soon after.

From 1846 to 1852 Capt. Wm. P. Parrott was associated with him, perhaps in some kind of co-partnership.

In 1846 Mr. Nott was engaged in work preparatory to the relocation of the main line of the Boston and Maine Railroad, from Andover to North Andover, to reach the new city of Lawrence.

In 1847 he and Capt. Parrott made preliminary surveys and estimates for the proposed Manchester and Lawrence Railroad.

The capital was oversubscribed, and early in 1848 Mr. Nott was made Chief Engineer, by contract with the Board of Directors. As the work progressed, differences of opinion arose as to locations and as to the selection of assistant engineers, resulting in a vote of a majority of the directors to displace Mr. Nott. On appeal to the stockholders, the minority directors and Mr. Nott were sustained by a large majority, and he continued as Chief Engineer till 1850, some time after the road was opened for business.

In 1848 he made a report to S. S. Lewis, President of the Grand Junction Railroad and Depot Company, of a survey from Malden street, in Chelsea, to the B. and W. R. R. at the "Ship Yard" in Brookline; and the building of the Junction Railroad followed a few years later.

In 1849-50 the Portsmouth and Concord Railroad had been located, and a large part of the masonry and grading had been completed; then the work stopped for want of money. Soon after that Mr. Nott took hold and carried the road through to completion and operation, but it was inadequately financed and he was left under a heavy load of personal liability.

Instead of seeking to evade his obligations, either legal or moral, under a discharge in insolvency, he manfully devoted his energies, for many years thereafter, to the making of full payment. He reduced expenses, removed his office to No. 6 Niles Building, and worked for this end with much industry and self-denial.

It will be seen from the above that he had much to do with many parts of the lines now controlled by the Boston and Maine Railroad Company; also that he was in demand as a man well qualified for railroad location and construction.

In October, 1852, with Robert Harris (who was afterwards a noted railroad manager) as a transitman, he began surveys for the extension of the Hartford, Providence and Fishkill Railroad, from Hoadley's, near Waterbury, to Fishkill-on-the-Hudson. Thorough explorations were made, and the line selected by him was followed with but slight changes when other good engineers took up the construction.

In the early history of the South Boston Flats, which have now become so valuable, Mr. Nott and Samuel Felton were appointed by State authority to fix the grade for the filling. They decided upon elevation 16 feet above mean low tide, which has proved satisfactory and is still adhered to.

On April 1, 1857, Mr. Nott was appointed Superintendent of the Hartford, Providence and Fishkill Railroad, and he continued in this position till his resignation (consequent upon a change of

control) in October, 1878. In consequence of this appointment, he removed to Hartford, and made his home there for the rest of his life.

The superintendency of a railroad then was a more important office than is designated by the same name now, the only operating officers not entirely under his direction being the Secretary and Treasurer, and even their work was largely done as he suggested. He took the road under the most adverse circumstances, with no credit and in a time of great financial depression. The greatest care was taken and the most rigid economy exercised, and when Mr. Nott left the road it was in fair physical condition and the earnings were considerably in excess of maintenance and interest charges.

From November, 1880, to May, 1882, he was Superintendent of the Hartford Water Works.

Thus his activity in strictly engineering work mainly ceased when he was 42 years of age; and he did but little in railroad work of any kind after his 64th year. But he did not lose his interest in railroad construction, maintenance and operation, nor in general engineering and progress. He was the author of interesting articles which appeared in the *Locomotive*, published at Hartford, under the editorship of J. M. Allen, who had the highest regard for Mr. Nott, and understood and appreciated his abilities.

We find in the archives of this Society two reports or investigations participated in by Mr. Nott.

First. "On the Destruction of the Dam at Hadley Falls" (now Holyoke). This was presented to the Society January 10, 1849. He describes the construction of the dam and the appearance of the parts not carried away. Another paper, presented by Capt. Parrott, apparently at the same meeting, undertakes to discuss the cause of the failure.

Second. A report of experiments for testing the merits of "Baker's Improved [boiler] Furnace." In this, he acted with other members of the Society. This report was read July 1, 1850, and ordered to be printed for distribution among the members.

Mr. Nott never married, but he was always a helpful son and brother. He was a good friend to the poor and needy, and few knew how much he was constantly doing to help and encourage them; the whole community was the better for his living in it.

He was a close observer of all missionary work and wrote "The Opened Door," a missionary story which has been enjoyed by many readers. He was active as Secretary of the Widow's Home, in Hartford, and was identified with the work of St. Paul's,

which was for many years a missionary church. Later, he was a communicant of St. Thomas' Church, in Hartford.

He had the nicest sense of honesty and honor, both in private life and professionally. In fine, he honored his Christian profession by an exceptionally exemplary and helpful life. One of the writers of this notice (first named above) worked under his direction for many years and had excellent opportunities to know of this and of his worth and attainments. He knew Mr. Nott and his reputation among men for more than forty years, and never heard a disparaging remark concerning him. All who worked under him knew that they had only to do their best, for the interests of the property he represented, to be fully appreciated by him. The second-named writer concurs in this estimate, so far as a less intimate acquaintance may justify.

We think his uniform intention and general practice was to do exactly what was right, and that he had much influence in starting the new profession of engineering on correct lines.

William Scollay Whitwell.

By Francis Blake and Ernest W. Bowditch, Committee of the Boston Society of Civil Engineers.

William Scollay Whitwell, an honorary member and one of the founders of the Boston Society of Civil Engineers, was born at Augusta, Maine, May 23, 1809. After receiving a preliminary education in the public schools of Boston, he evinced a strong inclination to become a civil engineer, and fitted himself therefor by a course at the Lawrence Scientific School, followed by extended practical experience in several of the leading machine shops of New England, particularly at Dover, N. H.

Mr. Whitwell's professional life began with the railway age, and it is noteworthy that it continued until the total length of railways throughout the world exceeded 450,000 miles. His first engineering work was done on the Concord Railroad. Afterward he had charge of a division of the survey for the Western and Atlantic Railroad in Georgia from Atlanta then only a railroad village, to Chattanooga, Tennessee. He also surveyed the railroad line from Tallahassee to the east coast of Florida during the Seminole War,

and it was after he had finished the section in his charge that the Seminoles massacred several engineers at work on the line.

June 6, 1846, Mr. Whitwell was elected chief engineer of the Eastern division of the Cochituate Water Works for the city of Boston. This, the most important service of his professional life, which included the design and construction of the then famous reservoir on Beacon Hill, was brought to a successful conclusion on October 25, 1848, in the presence of a multitude of citizens gathered about the "frog pond" on Boston Common. After appropriate ceremonies, the Mayor inquired if it was their pleasure that water should then be introduced. There was a tremendous affirmative shout, and thereupon the gate was opened and a column of water 6 inches in diameter rose to a height of 80 feet.

Mr. Whitwell was one of the twelve men who attended, on April 26, 1848, an informal meeting which led to the foundation of the Boston Society of Civil Engineers on June 15, 1848. Fifty years later, it was a cause of keen regret to him that his great age and failing health prevented him from attending the semi-centennial commemoration of the foundation of this honorable Society. On that occasion Mr. Whitwell and Messrs. John H. Blake and Samuel Nott were the only surviving founders; and it is a fact of mournful interest that these three men have since died during the same calendar year.

With the anti-slavery agitation Mr. Whitwell joined the ranks of the abolitionists, but he was a follower rather than a leader. Though taking no active part in the Civil War, all his sympathies were with the North and the Republican party. For many years he was managing treasurer of the Boston and Roxbury Mill Corporation, a very successful land company. The later years of his life were passed in travel at home and abroad, with residences of many months in various parts of Europe and America, including the resorts of his early manhood in Georgia and Florida and long visits to the Pacific coast. Although increasing age prolonged his periods of restful life in Boston and its neighboring towns, his taste for travel continued until the end. Only a month before his death Mr. Whitwell visited Quebec, and returned with improved health to the home of his younger daughter, at Hancock, in the New Hampshire hills. There, on October 31, 1899, he passed away quietly with the falling leaves during the last hour of the most beautiful of autumn months.

On September 30, 1844, Mr. Whitwell married Mary Greene, daughter of Henry and Mary Hubbard, of Boston. Three children survive him, William Scollay Whitwell, M.D., of San Mateo, Cal.;

Miss Mary Hubbard Whitwell, of Boston, and Elizabeth, wife of William Tudor, Esq., of Boston.

Sumner Hollingsworth.

By John R. Freeman and Charles T. Main, Committee of the Boston Society of Civil Engineers.

Sumner Hollingsworth was born on March 1, 1854, in South Braintree, Mass. He was suddenly taken from our midst on June 26, 1899.

His father, Ellis Anderson Hollingswort, was the son of Mark and Waitsill Hollinsworth, who came to Milton, Mass., from Pennsylvania, where they had been living on lands deeded by William Penn. On the maternal side, also, he decended from a distinguished family, his mother, Susan J. Sumner, being a cousin of Charles Sumner.

His early life was spent in South Braintree, where he attended the public schools. From there he came to the Chauncey Hall School, and in 1872 entered the Massachusetts Institute of Technology. It was here that the writers became intimate with him, and this intimacy grew into a strong and life-long friendship. It was here that his strong intellect forecast its future in the ease with which difficult problems were mastered, and the essence of the subject at hand was extracted with no apparent effort. His wonderful ability of getting at the real substance and of its proper application, and the strong memory by which it was retained, were known only to his few most intimate classmates. This ability he held in a very marked degree throughout his business career. The years of student life were passed quietly and apparently with great ease, as far as regular studies were concerned, and time was found for broader reading and study on non-professional subjects. His rank was always high.

Graduating from the institute in the department of mechanical engineering in 1876, he entered the employ of Hollingsworth & Whitney in the business of paper manufacturing, with which he was very familiar before graduation, his thesis being on that subject. In 1881-82 the Hollingsworth & Whitney Company was organized, and Sumner Hollingsworth became president of the company after his father's death in 1882.

It was in this position, at the head of a great company, that his engineering ability had ample scope. The many problems which are to be solved in the construction and running of large paper mills were studied and solved. He was familiar with the construction of buildings, the arrangement and production of machinery, the economical production of power by steam and water and the transmission of power in various forms. He was also familiar with questions of labor and of markets for the purchase of raw materials and the sale of finished product. He often made investigations into subjects connected with the manufacture of paper on which there was little or unreliable information obtainable.

An illustration of the care and thoroughness of his investigations is the fact that, in order to carry on some of his experiments on evaporation and upon the transfer of heat and to feel absolutely sure of the results, he ordered from Paris, through Professor Holman, standard thermometers of the finest grade, which were standardized at the International Bureau of Weights and Measures. These thermometers were the first of that character to be obtained by the Institute of Technology and by Harvard College, so that Hollingsworth must have been one of the first, if not the first engineer in this country, to personally take advantage of the admirable opportunities afforded by the bureau.

Of a very retiring nature, none but his most intimate friends knew of these investigations and their interesting and valuable results. Had he been more outspoken in public his great ability would have received immediate attention. He was able to grasp in a masterful way all of the various problems which went to make up the whole and assimilate and weld them into one, each having its true proportion and each part performing its function in a manner to obtain what is known as the highest commercial efficiency.

Hollingsworth became a member of the Boston Society of Civil Engineers in April, 1894. He was also a member of the American Society of Mechanical Engineers and of the Society of Arts; also of the Technology and Union Clubs, and of the Club of Odd Volumes. He was a charter member of the latter club, and he was very much interested in the early colonial history literature of our country. He collected the finest and most valuable private library of that description, with one exception, in New England.

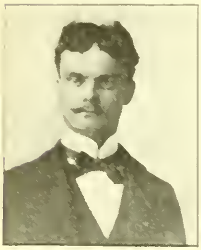
In 1887 he was married to Miss Mary Clapp Stevens, of Gardiner, Me. His home life was his real life, and "it was here that all that was sweetest and best in his nature shone the brightest." The winter months were spent in Boston, at their home on Fairfield street, and the summer months were spent with great delight in the

old Sumner mansion in Milton, which for more than two centuries and a half was the home of the Sumner family.

It has been a great pleasure to have known Hollingsworth, and we regret that it has not been the good fortune of every member of the Society to have known him also.

Harry Herbert Hirst.

By H. I. Randall and Frank Soulé, Members of the Committee, Technical Society of the Pacific Coast.



After a lingering illness of several months' duration, and poor health extending over several years' time, Harry Herbert Hirst passed from this life on December 23, 1899.

Although the seriousness of his last illness was realized by his friends, still, when the end came, his death cast a cloud of sadness over the community in which he lived.

He was born May 1, 1873, and therefore at the time of his death was in his twenty-seventh year.

After preparation in the San Francisco Boys' High School, he entered the University of California in August, 1892, and four years later was graduated with the degree of B.S. from the College of Civil Engineering, being awarded at the same time the university medal annually bestowed upon "the most distinguished graduate of the year."

As a university student he excelled not only in his studies, but also in the active interest he took in student affairs. In his senior year he was president of his class, president of the Associated Students and editor of one of the college papers; and during his entire undergraduate life he was an active and influential member of the Sigma Nu fraternity.

His professional career, although not extended, gave promise of being a very able, useful and honorable one. Before entering the university he had been assistant engineer to the Grant Bros., of the Moraga Land Association, in connection with various enterprises. At the University of California his marked ability was early recognized, and even before graduation, in his senior year, he was appointed assistant in surveying and field practice. In May, 1898, he was promoted to be instructor in civil engineering at the university. This position he held at the time of his death, although

absent on one year's leave of absence on account of illness. In September, 1899, he was commissioned by the Bureau of Irrigation of the United States Department of Agriculture to investigate the water supply and irrigation question in Southern California. On account of ill health he was unable to carry out this last work.

He was a member of the Technical Society of the Pacific Coast from February 5, 1897, until the time of his death.

Mr. Hirst was gifted with a winning personality, an exceptionally manly character and a genial disposition, which won for him many friends; while his strong, original mind, and diligent, systematic work caused him to be held in high estimation by those who knew him professionally.

In his death the Technical Society lost one of its youngest, yet one of its most promising members.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

THE RECONSTRUCTION OF THE BIG HOLE DAM.

BY JOS. H. HARPER, MEMBER MONTANA SOCIETY OF ENGINEERS.

[Read before the Society January 12, 1900.*]

THE dam of the Montana Power Company at Divide has attracted an unusual amount of attention owing to the fact that the original structure failed in part on first taking its burden, and on this account, too, the work has attained a degree of interest for our profession which it would not have possessed had it been entirely successful in the first instance.

I shall not attempt a description of the original structure, as a majority of my hearers have examined it in person, but shall refer those who have not been able to do so, and who are interested in tracing the history of the work, to an article published in the *Engineering Record* of March 5, 1898, for a comprehensive statement of the original plans and purposes of the Montana Power Company, with a description of the proposed power and transmission plant; and to a paper on the "Partial Failure of a Timber Crib Dam" prepared for the twelfth annual meeting of this Society by our fellow-member, Mr. M. S. Parker, and published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for April, 1899, for further interesting notes and tests upon Montana timber, which are of value to the profession in general and quite as interesting to those using our timber in other lines of work as to those who may wish to use it in the construction of dams and reservoirs.

All my co-workers, and I think every member of our profession with whom I have discussed plans for repairing this dam,

*Manuscript received March 6, 1900.—Secretary, Ass'n of Eng. Socs.

have agreed fairly upon the general methods that should be adopted; the only important feature upon which a difference of opinion seemed to exist related to the proportion of the distorted structure it would be necessary to remove before beginning the new work.

Our views upon this point are set forth in a report to the Montana Power Company, made by Harper & Macdonald in the summer of 1898, in which we claimed for the distorted structure much reserve strength, for the reason that the aprons, which consisted of a double deck of 10 x 12 timbers, thoroughly drifted together, though displaced and badly tilted at some points, were in the main lying horizontal and occupying such a position as to act as girders or web members in sustaining the water pressure; and for the further reason that the material and filling had practically "settled." The dam as a whole had completed its journey and found its place of rest, and, though an apparent wreck in many respects, it had taken its burden and was at that time carrying it successfully with the water level in the reservoir but five feet below the working head.

If we differed in any way from our brother engineers it was in our advice to leave as large a portion of the old structure undisturbed as was possible, to secure a thorough bond between the old work and the new and to introduce every possible device to "catch up" and retain the old structure in the position it then occupied.

Our plan for accomplishing this is illustrated in Fig. 2 (which is a cross-section through the line of maximum movement, with the dividing section, buttress members and old sluiceways projected in dotted lines), and consisted in forming a series of buttress members or struts, not less than 3 feet square at the base and continuing a width of 3 feet to the top, from the toe to the top of the old structure, with the successive leaves or courses of timber upon the under side abutting against and bracing the lower and longitudinal courses of the successive aprons of the old work, as shown.

Another feature, which was introduced later, and which I shall briefly note in this connection, is shown in Fig. 4, and consisted in working two horizontal courses in the top of the dam and placing 2½-inch x 28-foot iron rods therein in the manner shown, dividing the course into five truss members, 32 feet (4 cribs) between the panel points, and situated at an elevation of 6 and 10 feet below the crest, as indicated on the cross-section shown in Fig. 2.

When the position of these panel points is noted with reference to the buttress members above referred to our object in introducing the truss rods will be apparent, but this plan would not have been considered nor the system introduced had it not been that the rods were already upon the ground, and were practically scrap iron on the hands of the company, as that portion of the fore bay for which they were originally ordered had been abandoned and a steel pipe used instead.

The distortion of the crest line of the old structure, as you will recall, was about 14 feet at the point of maximum movement, and on considering the dimensions for reconstruction it at first sight appeared necessary to move the new crest line down the stream for this distance and to add 14 feet to the entire lower face of the dam before we could get even the proportions that existed in the old structure. That is to say, if the crest line were moved to avoid an "overhang" of the new work on the upper face and 14 feet added to the entire lower face of the structure, a cross-section through the point of maximum movement would show the same angle from crest to toe that existed in the old structure, and this was regarded as entirely too steep for the maximum discharge of the Big Hole River.

This method seemed to require a very large amount of work and to accomplish apparently very little, while to build with the upper cribs of the new work overhanging on the upper face was doubtless very awkward construction; but was of necessity adopted and satisfactorily accomplished by furring with 3-inch plank upon the depressed portion of the old face to a new face line which was established 5 feet further down stream, our ability to get nearer the original face being barred by the location of the lower gates in the old structure through which the flow of the river was being taken.

This furring was built up solid of 3 x 12-inch planking, as shown, thoroughly spiked with 12-inch boat spikes on every course, thus forming a member that served the double purpose of distributing the weight of the overhanging cribs evenly over the upper face of the old work and adding greatly to the strength of the dam in that portion that had been demonstrated as weakest.

I am not disposed to criticise the plans offered for the old structure, as I do not feel that my experience has been general enough to warrant it, but I must call your attention to some of the objectionable features developed by a practical test, the first being the part played by the vertical sheeting in distorting the aprons.

Here we have a crib structure, the members of which we anticipate will be compressed by the weight of filling, and will be

sure to shrink on seasoning, sheeted along the lines that are to bear the lightest burden by planking on end in a manner that would prevent its settling upon these lines in the slightest degree. The plan would certainly be improved by using the sheeting with the grain running longitudinally, in which position it would shrink and settle with the other timbers, all of which are used with the grain running horizontally. At any rate, if so placed it would not carry up the outer ends of the aprons and prevent the normal settlement which will take place in all parts of the work.

In rebuilding we abandoned entirely the idea of sheeting, and used the style of construction shown in Fig. 2; and though somewhat more timber is required, the additional amount is fairly offset by a saving in labor and spikes. Fig. 3 shows the face of the dam when finished in this manner, with the ends of the lateral courses projecting and showing through the longitudinals, a feature which I think gives the structure an air of stability that it would not otherwise possess, as it suggests the character of bond used throughout, which is all concealed if the face be sheeted over and the crib work entirely covered.

Another slight change in arranging timber was made in this. In the original plan both of the deck courses were worked on the flat, that is, the 10-inch way, while the timbers in the body of the dam, belonging to these same courses, were worked the 12-inch way, thus forming an unbroken joint across the dam on all lines where the decks joined the main cribs. In the new work the two deck courses were extended the 10-inch way over the entire surface of the dam.

This change permits the upper timbers of our deck course to extend over the first internal tier of cribs and into the body of the dam, thus breaking the continuous joint along the lines that had shown the greatest weakness in the original work and introducing a feature that we are certain will assist greatly in bearing up the outer walls of the exterior line of cribs rising from this point.

The original plan shows all timber for the crib work as squared off and butted end on end, while for the reconstruction the timbers were ordered 2 feet longer and were allowed to lap at the ends, as shown in Fig. 4. This method of building requires about 10 per cent. more timber, but the additional quantity is placed where it will give the best service in preventing settlement and leaves timber enough at the ends of the stick and beyond the drift bolts to "hold," in this way obtaining from the drift bolts much more effective work than is possible when they are driven within 3 inches of the end of the stick, while the labor saved by using the sticks as they come

from the mill, without squaring off, will go far toward paying for the extra timber required.

The change above mentioned I can heartily recommend for general use in the lower courses, and at all points where the burden is heavy and we have anything to fear from the compression of timber. Indeed, I think it will be found the cheapest method of doubling up and securing against failure from this cause.

Before the work was started, Mr. Parker and the writer discussed with apparent accord the great utility of lateral blocking when used as suggested in the paper above referred to, and it seems particularly unfortunate that a principle of such obvious merit was not more generally introduced in the original structure. Its value in crib construction is not likely to be overestimated by our profession, but you should note that to secure the maximum advantage the blocking should be done in the lower courses of the dam, and particularly through that portion where the greatest pressure is exerted; for its efficiency is rapidly impaired as we approach the toe of the structure where the binding forces are light, and its utility diminishes rapidly as we approach the crest line. Though adopted and generously used in the work of rebuilding, we regarded it in this instance a matter of secondary importance, as it was impossible to get the blocks where they were most needed and could render full service, which was in the inside and lower courses of the dam.

I cannot, however, agree with Mr. Parker when he suggests the use of diagonal bracing for a crib dam, as the settlement, some of which the structure must always endure, will tend to load these members to rupture before the drift bolts and blocking can begin to take their load; that is, the diagonals and the blocking will not assume the burden in fair proportion, and any settlement will but serve to emphasize this lack of harmony.

I do not mean to say that we would not find locations where diagonals could be used to advantage, but, if so, I think the entire structure should receive different treatment and the diagonals made strong enough to carry the entire water burden. The stability should be secured by anchorage instead of filling, and, in short, such a location would probably call for a steel and not a timber structure. To me diagonal bracing seems out of place in a timber crib structure, and though this estimate of its value may seem inconsistent with the use of the buttress members described above, you will notice that these members are an expedient resorted to for the purpose of "catching up" and utilizing the reserve strength of the old structure, and may be more properly regarded as a part of the old work rather than of the new.

Some provision for draining the water from above the dam is certainly demanded, and it was doubtless this consideration that led to the placing of gates and sluiceways through the old dam, as indicated by dotted lines on the cross-sections, a feature that, in our estimation, contributed in no small degree to the wreck that followed.

In the new plan these openings were all closed and the end accomplished by running a tunnel through solid rock around the north end of the dam, with an area at the waste of 35 square feet, capable of carrying the entire flow of the river and drawing the water in the reservoir below the level of the fore bay during the low-water period of each year.

The gate well for controlling this opening is not an ideal structure for the purpose, as it is built wholly of timber; but funds were not available for what we would have advised, and the shortness of the season, with the necessity for completing the work before closing the river gates, precluded all attempts at anything that could not be accomplished with the material and force already upon the ground.

The foregoing completes a hasty review of the field, in which I have endeavored to show the weak points developed in the old structure, the means proposed for strengthening it, features in which the rebuilding differed from the original work and some of the more important considerations that influenced our designs and controlled the work.

I will now compare briefly the dimensions and proportions of this dam as at first conceived, as originally built, as amended and as finally reconstructed.

I am frequently asked to assign a reason for the failure of the old structure, and, though I have had far better and more numerous opportunities for observation, and have studied the question with great care and attention, I confess myself unable to assign a first cause or to trace a predominating weakness, though I have noted several features that doubtless contributed to the general result. I can perhaps express myself upon the weak points by stating what I think might have saved it, for it is my belief that the dam came very near standing for the first year, at any rate.

I think if the system of lateral blocking first suggested by Mr. Parker had been used at intervals of 16 feet and drifted with three bolts through and three into the block the structure would have found rest with moderate movement only, and would have carried the water pressure successfully. Had the blocking been omitted and the cribs filled with clean rock I think the dam would still have

carried the pressure, though the movement would have been somewhat greater than in the case first mentioned.

Again, it is my belief that had either or both of the items specified been used, and had the dam carried water successfully for the first season, it could not have borne the discharge of the Big Hole River in a season of maximum flow, and would have failed at some subsequent period with consequences far more disastrous than those accompanying the movement of 1898.

We have made many measurements of the Big Hole River, and since the fall of 1896 have had a channel course 300 feet in length, with permanent gauges on the bank about one mile below the site of the present dam, over which we have usually caught the maximum and minimum and several intermediate readings for each season. We did not catch the maximum for the year 1898, but when the water of 1899 touched the highest marks made by that of the previous year our gauge indicated a flow of 5785 cubic feet per second.

Our maximum gauging at this point for the season of 1899 indicated a flow of 18,818 cubic feet per second, and a discharge for more than twenty-four hours which was three times as great as the maximum flow of the previous year. It is this excessive volume of the river's discharge, which apparently occurs at intervals of about ten years, a feature manifest in all our mountain streams, but particularly pronounced upon the Big Hole River, that leads to the opinion above expressed, that a dam built upon the original plan must have failed sooner or later.

The original plan for this dam arranged the steps for a run of 10 feet in a rise of 10, with the upper step 7 feet 6 inches in height and the lower apron 15 feet in length; but these proportions were changed before construction to give the aprons a run of 11 feet 8 inches in a rise of 10 feet, with the upper step 8 feet in height and the lower apron 20 feet in length.

A plan for reconstruction arranged the steps with a run of 19 feet 6 inches in a rise of 12 feet (which is equivalent to a run of 15 feet 10 inches in a rise of 10 feet), with the crest arranged to direct the falling water upon the exterior points of the aprons below, while the lower deck is given a length of 20 feet. The lines upon which the dam has been reconstructed arranged the aprons with a run of 22 feet in a rise of 12 feet (equivalent to a run of 18 feet 3 inches in a rise of 10 feet), with the upper step of 13 feet broken into a fall of 4 feet, followed by one of 9 feet, with the lower apron 20 feet in length, as before.

The base and altitude, when scaled from a point level with the crest, flush with the upper face of the dam to the outer point of the lower apron, for the four plans named are as follows: First, base length 84 feet, altitude 57.5 feet; second, base length 98.75 feet, altitude 58 feet; third base length 120 feet, altitude 58 feet; fourth, base length 130 feet, altitude 50 feet. Or the ratio of base when expressed in units of altitude is as follows: For the first plan, 1.46; second plan, 1.7; third plan, 2.1; fourth plan, 2.6.

These proportions can be more readily understood by referring to Fig. 5, wherein an outline of the different plans above named and an outline of the distorted structure are each represented with a different and characteristic line.

When you have compared the dam as first proposed with the one now upon the ground, and when I tell you that the river for nearly twenty-four hours made but two distinct leaps in its descent, and at the second landed half-way over the point of the lower deck, you will understand why we feel that that a dam upon the original lines would have given trouble sooner or later.

The original plan, as prepared by Mr. Fanning, provided for a large pier of concrete through what we know as the dividing section, near the center of the dam, but his plans were greatly modified in this respect before construction, by whom or at what time is not pertinent to my present purpose.

Had this body of concrete been placed as designed it would doubtless have saved that portion of the dam which lies south of this point, but I cannot think it reasonable to claim that it would have saved the dam proper; and I should expect a movement in the northern portion very similar to the one that did take place, as you will note the point of maximum movement is considerably north of the dividing section and well toward the center of the dam.

The people are very sensitive, justly so, and are prone to criticise the "style" of construction used, and suggest many things to replace the timber crib; but, barring a masonry dam, which, for economic reasons, could not be considered, I approve of the design in a general way, believe it the best possible selection and perfectly adapted for the site upon which it was placed.

A change often suggested is to extend the bottom upstream from the crest line, and use the sheeting in an inclined position, the idea being apparently to get the weight of a portion of the water upon the dam with a view of holding it in place. Another suggestion, and the engineers are given to making this, is to use the ogee instead of aprons on the overflow, but the advantages of this form

are generally overestimated, and in this particular instance I would greatly prefer the steps as used.

A reasonable limit for this paper will not permit further digression, and, as a fair discussion of the sheeting and the form of overflow would each furnish material for another paper, I must pass them with the following brief remarks on these subjects:

I approve of vertical sheeting (on the core or water face), and must question all efforts to obtain stability for a dam by weighting down with water; while if the height be more than 30 feet I cannot approve of carrying the burden upon an inclined core or sheeting course, as this arrangement will eventually give you trouble in more ways than one. An ogee will, without doubt, let the water over the dam in an ideal manner, but timber construction does not lend itself readily to this form of overflow; and by its use we cannot avoid the striking force of the stream which will be the product of pounds of water into feet of fall, into units of time, and a neglect on our part to work this problem and provide for the resultant at the toe of the dam will not be overlooked by the river when fairly started upon its season's work.

Our estimated maximum discharge was usually regarded by engineers who saw the river at its normal stage only as too high, but in May, 1897, I obtained a measurement of 5330 cubic feet per second; and by comparison with older and higher marks estimated that the river would often discharge a volume of 7500 cubic feet, and in exceptional seasons the maximum discharge would reach 10,000 cubic feet per second.

Our preliminary calculations for a dam at this point anticipated a crest width of 300 feet, the probable maximum depth upon the crest as 5 feet, but the dam was constructed with the crest width reduced to 200 feet, thus increasing the probable depth over the dam to about 7 feet, if our assumption as to maximum discharge should prove correct.

The actual discharge of the river on June 20, 1899, was very nearly twice the maximum anticipated in our preliminary estimates and report of 1897.

You have probably noticed, and with surprise perhaps, the permanent posts rising through the crest of the dam, as shown in Figs. 1, 2 and 3, and we wish to say in advance that we are not champions of this style of construction, and we are well aware that on general principles the profession must condemn their appearance upon a spillway. The old crest line was established at a datum elevation of 58, the working water level required to obtain a clear head of 60 feet above low-tail water. Our study of the company's

flowage rights at what we call the Flat fixes our high water limit at a datum elevation of 62, which, with our crest established at 58 feet, gives but 4 feet between the crest and our high water limit, a depth entirely inadequate for the river's discharge, as we were apprehending about 7 feet over a spillway 200 feet in width.

The crest was therefore reconstructed at a datum elevation of 54, and very shortly afterwards the wisdom of this action was abundantly demonstrated, for on June 20 our maximum reading was 62.66, giving a theoretical depth on the crest of 8.66 feet, or when corrected for the settlement (since determined) the water actually reached a depth of 9.50 feet near the south end of the spillway.

I regarded it as almost certain death for a man to go over the dam with even 4 feet of water upon the crest, and yet the limiting conditions above mentioned compel us to begin to replace the flush boards at this point if we are to maintain a working head of 60 feet. We have not been able to discover or devise a moving support of any kind that we felt would work satisfactorily, and the permanent posts as you see them is our solution of the problem presented.

Our plan contemplates the protection of the dam from driftwood and running ice by a substantial boom across the river about 1000 feet above the site, and by two sheer booms that will guide this material, when it is allowed to run, to the open space provided for its passage near the center of the dam.

A receiver for this property was appointed October 20, 1898, and arrangements were immediately made for the execution of the work with Messrs. Winters, Parsons & Boomer (the former contractors) at the following prices:

For rubble masonry, cement furnished by company, $6.50 cubic yard.
For cement concrete, cement furnished by company, $5.00 cubic yard.
For rock filling, $0.50 cubic yard.
For timber in place, labor only, $6.00 per 1000.

Approximately, 1,350,000 feet of lumber was used, and about 12,000 cubic yards of rock filling placed in the repair of the dam proper; while about 1500 yards of earth and rock has been filled in front of the dam and nearly 1000 yards used to strengthen that portion of the dam south of the fore bay.

Harper & Macdonald were engaged to superintend the reconstruction October 25, and the actual work of repair was commenced on October 26, with the writer as engineer in charge.

The first timber on the Silver Bow half of the structure was laid November 21, 1898; the lower gates were closed March 6, and the crest of the restored structure finished on April 16, 1899.

The dominant note of the work has been to spare no reasonable expense that would add to the stability and strength of the structure, and in maintaining this tone it is a pleasure for the writer to state that he has been most cheerfully seconded by Mr. F. T. Sterling, the receiver, and very generously supported by the gentlemen who have furnished funds for the purpose.

It is quite impractical to prevent movement and settlement in structures of this character, and I regard the refinements so often specified in an effort to do so as money spent for a trifling purpose, believing it to be better policy and more effective practice to increase the dimensions and the quantities of material used.

On this work but little time was devoted to the sizing of timber, barely sufficient to get a bearing and maintain a general grade on the cribs; but honest work was required everywhere. Timber was generously used, and the whole securely blocked and thoroughly drifted. No time was spent in leveling rock in the new fill, but extra care was taken in stowing all voids under the old aprons with selected material; and no opportunity of tying to the old structure was neglected, and these bonds were made as secure as possible.

Every effort was made to obtain clean rock, and to prevent such fine material as we were obliged to handle in filling the cribs from banking in a manner that would prevent actual contact of rock with rock. It is hardly practical to exercise greater care, and it is rarely possible to obtain better material than was used in this work. But it will not matter how excellent the material or how carefully placed, we must anticipate some further movement when the water first goes through, and still another when it begins to carry the burden of the river.

The movement in this structure was divided into three well-defined stages, and I have already referred to the first as amounting to 0.2 in a height of 12 feet which occurred while the filling was being done. I noted a further settlement on its first taking water, while I found the maximum settlement upon the crest line near the south end of the spillway to be 0.6 feet after the high water had passed. The successive deflections on the top of the dam at a point 14 feet above the crest, and the final movement at the crest line and the successive stages of settlement, so far as determined, are shown in the outline plan and elevation, Fig. 6.

One feature which I noted and regarded as interesting was that the deflection was accelerated as the water began going over the crest, due, without doubt, to an acceleration in the settlement which occurred at this time, and which I attribute to the thorough soaking of the material in the cribs.

Were I doing this work again I would advise the wetting of this material while filling, and if necessary would place a pump for this purpose, as I think the deflection might have been reduced some 25 or 30 per cent. if the first and second periods of settlement, amounting in this case to about 0.4 feet, could be accomplished before the dam began taking its water burden.

This further confirms my belief that clean rock is the only material available in ordinary practice that should be used in filling cribs. It may be comparatively fine, say of the size of eggs and nuts, if absolutely clean and so placed that every individual unit shall come in contact with the surrounding units without being cushioned off by sand, clay or other material; and though I should anticipate a greater movement from a fill of this kind than if the rock were as large as pumpkins and melons, it would not prove in any way disastrous.

Mr. Fanning and Mr. Parker, who have preceded me in this work, are both men whose integrity is beyond question, and whose experience in this class of work has been broader than my own, but I am compelled to differ from them in the conclusions reached and in the lessons we may learn from our experience with it, and will preface my closing remarks with the assurance that nothing I may say is offered in a captious spirit, or with intent to criticise, but that every utterance is born of a desire to be professionally honest with the facts, candid with the results and friendly in my conclusions.

It is not altogether fair to hold the designer responsible for the failure of a structure when the plans have been so greatly changed before executing the work as to omit the concrete dividing section hereinbefore noted.

I have indorsed this plan in a general way, but I cannot leave the subject without saying that, in my estimation, Mr. Fanning's dimensions are too small, his quantities meager and his dam too light; in other words, the factor of safety is insufficient. Granting, for the sake of argument, that a dam can be built upon the original lines in a manner and of material that would have withstood the quiescent water pressure of the reservoir, the angle from crest to toe is quite too steep and the design poorly calculated for carrying the river's maximum discharge; in short, I do not think such a dam could have borne the "hammer" of the river.

Of the character of the filling I have no personal knowledge, and am well aware that my conclusions will be questioned by many whose opportunities for knowing just what was placed in the dam were much better than my own, and I shall confine my reasoning

to the recorded facts as manifested by the appearance of the distorted structure, and from which I think we must conclude that those who assert that the filling was all that could be desired have been greatly deceived or much mistaken.

Mr. Parker states that "fully 90 per cent. of the filling was broken stone." I can understand how 10 per cent. of fine material can be used in the voids with perfect indifference, and I can as readily understand how even 5 per cent. of such material, if allowed to bank at any point, might prove very detrimental.

The maximum settlement has been given as 4 feet at the crest, and it was rather more than this at the lowest point in the upper sluiceways through the dam; and, though much less at many points, was 3 feet or more on all the higher portions of the work. This is certainly more than our general practice would anticipate in a clean rock fill of 60 feet, and to me the conclusion is unavoidable that too much material was used that could be and was displaced by the water.

The loading of timber is a subject that should be considered at all times, and its undue compression carefully guarded against, but I cannot regard this feature as an important element in calculating the stability of a rock-filled timber crib.

I am not sure that I follow the writer in the computations he has placed before us upon this point, but I can see no reason for assuming that the loading is concentrated upon the timbers at the corners of the cribs; or that the timber can in any way be called upon to carry the entire weight, or, indeed, any great portion of the weight of the dam.

Is it not as reasonable to presume that the filling will in a measure "carry up" the timber members of the structure? And, in fact, is it not most reasonable to assume that every superficial foot of the base of the structure carries, approximately, its proportionate share of the loading, and that the timbers which are surrounded and encased in the material used for filling will be compressed and settle with it; and that the timber elements of the structure will not be overloaded or compressed to a detrimental degree unless there is an unnecessary and detrimental degree of settlement in the material of which the fill is made? In other words, as I read the record of events, the partial failure was not so much due to the compression of timber, but rather that the excessive compression of timber has been occasioned by a partial failure of the filling.

If there are crib structures higher than the one under discussion I am not informed of their location, and I do not think that anything so high has ever been attempted upon so large a stream

as the Big Hole River. I quite agree with Mr. Parker when he says that the limits have not yet been reached in crib construction, and on small streams with favorable bottoms and banks I can see no reason why crib dams 75 and even 100 feet in height may not be successfully constructed, though the economic conditions and environments that would render such a structure advisable are exceedingly rare; and I do not remember to have met with them in my practice. Indeed, I think the present structure has considerably exceeded the economical limit for that locality.

On the other hand, where the stream is as large as the Big Hole River, I think we are very close to the practical limit at 60 feet, for the timber aprons are pretty severely punished for three months in every year under this head.

DISCUSSION.

Mr. Keerl.—If not inconsistent, I would like to ask Mr. Harper if he can give the horse power that can be delivered in Butte, and whether he feels prepared to give us a stat ment of the cost of this work, both as to the dam and the power house, electrical machinery, the amount of horse power developed at the dam and the net amount that can be delivered in the city?

Mr. Harper.—That is a field in which we have not been employed. Mr. Max Hebgen, of Butte, and a member of this Society, is superintendent of the plant and the transmission line to Butte. The horse power anticipated is 1200 theoretical at each water wheel, or 1000 net from each dynamo. The four water wheels are in place, but only two of them have been connected and are at work. The cost of a horse power delivered is a complex question, and one which I do not think the owners have yet answered to their satisfaction.

The Chairman.—If you were designing a crib dam, irrespective of the old structure, would you make a vertical face next to the water?

Mr. Harper.—Yes, sir.

Mr. Carroll.—I do not fully agree with Mr. Harper in regard to the vertical face. From my experience, and from observation of this failure, I believe the incline face to be the best and most economical construction. It seems to me that the water face should be placed upon an incline approaching the angle of repose of the material used in filling the cribs.

I quite agree with him in the statement that only a small amount of light material should be used in the crib filling. I came to this conclusion from my experience of three years ago, during

the building of a crib dam about 40 feet in height for the Butte City Water Company, on Basin Creek. At this point we had plenty of rock and decomposed granite close to the structure, and made the filling 75 per cent. broken rock and 25 per cent. of decomposed granite, which was thoroughly flooded with water. The filling made in this manner was very compact and apparently very satisfactory, but when the water was turned into the reservoir the leakage through the face washed considerable of the decomposed granite out of the fill; and I came to the conclusion that it would have been much better to have made the filling of the cribs entirely of broken rock, using only a very small amount of fine material to fill the crevices and solidify the filling to support the face when the water was first turned in. It seems to me that it is better to have too little fine material, or none at all, than to have too much.

Mr. Harper.—Mr. Chairman, I think we agree fairly well upon the manner of filling, but apparently differ in our methods of arranging the face. My experience has led me to believe that the proper position for the sheeting courses, which in this style of construction performs the service of a core wall, is a vertical one. Let this member be perpendicular, so that the filling as it settles may press more firmly upon the back, where it is most needed and where it can accomplish most in resisting the water pressure. In all high structures the inside filling should be, in part at least, counterbalanced by filling upon the water side of the facing.

Mr. Harrison.—What is the probable life of such a structure? Does the water percolate through and keep the dam saturated?

Mr. Harper.—I cannot fully answer that. I have a pretty clear idea of the inside of one of these dams, and I believe they are always damp. When the water is held above the crest the dam will be pretty thoroughly wetted, and the timbers will not rot very fast; but the aprons will in time decay and be worn away, though they may last for ten, fifteen or perhaps twenty years. When they do fail, however, it does not mean that the entire structure must be rebuilt, for it can be reinforced by resheeting the aprons and, where the outside timbers are badly decayed, by cutting through the aprons and driving piles, to which we would anchor the new work.

Mr. Hollinshead.—Mr. Harper appears to approve of vertical sheeting, and yet I understood him to criticise this feature of the early plans.

Mr. Harper.—My use of the word "sheeting" to designate two very dissimilar members of the dam is somewhat confusing. My first reference was to the sheeting as used on the down-stream face of the old dam, and my objection was based upon its action in tilting

the aprons in the manner shown on my cross-section at the point marked A, B and C. Further on in my paper I use the same term to designate the covering on the water face, probably the most important element of the dam; the element that stands for the core wall; in fact, the member that forms the dam. This, I believe, should always occupy a vertical position, and the timber of which it is composed be placed with the grain running perpendicularly.

Mr. C. D. Vail.—During the maximum flow, did the water take one or two steps in clearing the dam?

Mr. Harper.—Up to a flow of about 5000 feet the action of the water in going over the dam was ideal, and it was very nicely broken upon every apron until about 10,000 feet had been reached, when it began to shoot out from the central aprons and strike upon the points of those below; and as the water reached a higher stage this tendency became more pronounced, until at the point of maximum discharge the visible surface of the river was leaping from the crest, striking near the point of the third apron and leaping again to strike just beyond the point of the first or lower apron, thus practically clearing the dam in two leaps. This was the apparent or visible action, though we know, of course, that beneath the surface the water was being more or less effectually broken upon every step.

Mr. Harrison.—What did you state concerning the vibration of the dam?

Mr. Harper.—In response to two or three queries that have been made concerning the vibration and the burden on the dam, I would say that the maximum vibration seemed to me to have passed before the highest water came. Should the water continue to rise over the dam all steps in the overflow would finally disappear, and the surface of the river over the dam would become one great roll or riffle. The burden beyond the toe of the dam would doubtless be much heavier, but I do not think the burden upon the aprons would have been greatly increased by higher water.

Mr. Harrison.—I would like to ask you, Mr. Harper, if the ogee is not the best form of overflow?

Mr. Harper.—I approve of the ogee. It is my favorite form whenever practicable, but, as before stated, timber construction does not lend itself readily to forming the ogee. By largely increasing the number of steps and making those near the top of the dam short and high, while those at the toe are low and long, this form may be approximated, as illustrated by the detail in Fig. 2.

Mr. Carroll.—From your statement, that makes an ogee of it.

Mr. Harper.—That is true. The plan would require an additional amount of timber as the apron courses are increased in num-

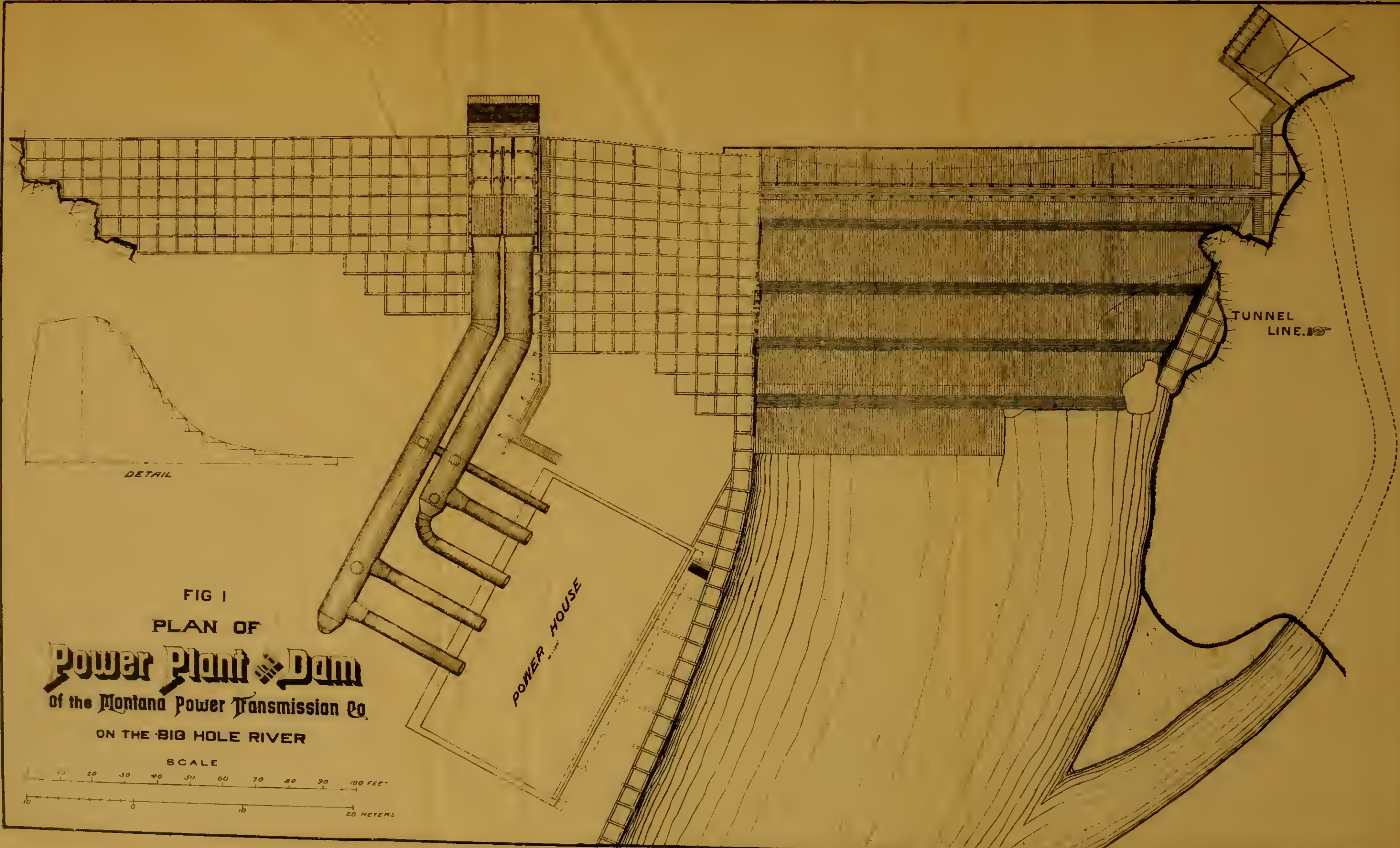

FIG I
PLAN OF
Power Plant and Dam
of the Montana Power Transmission Co
ON THE BIG HOLE RIVER

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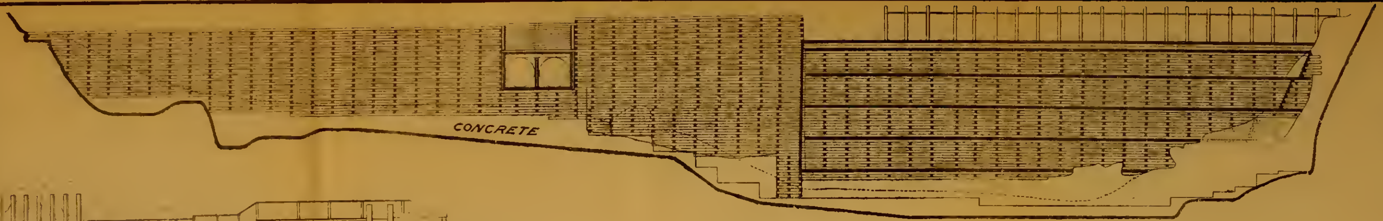
ELEVATION AND SECTION OF

Power Plant and Dam

Of the Montana Power Transmission Co.

ON THE BIG HOLE RIVER



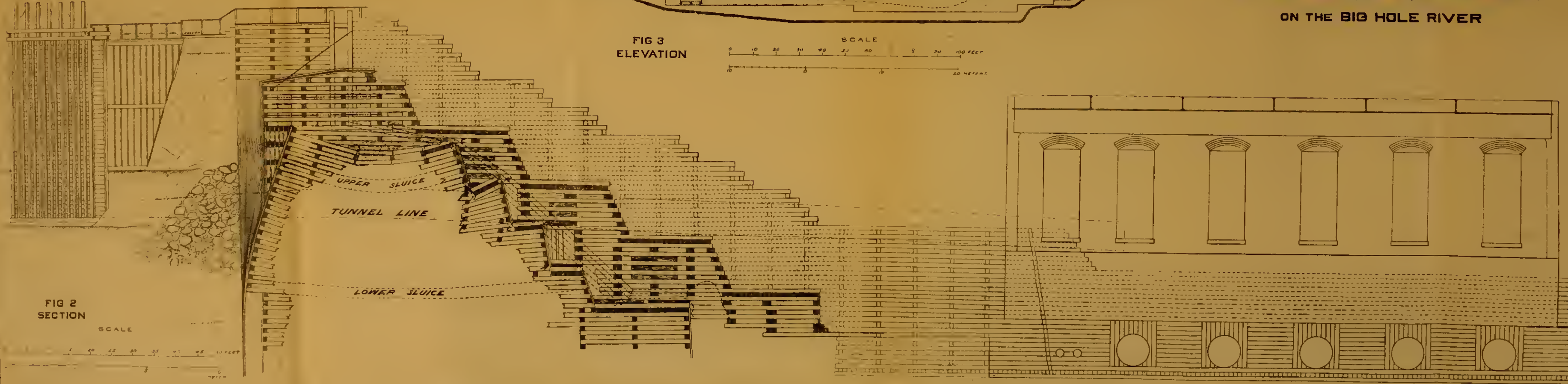


FIG 3
ELEVATION

FIG 2
SECTION

EXPLANATORY NOTES FOR THE ELEVATION AND PLAN. FIG. 6.

Reconstruction of Big Hole Dam, by Jos. H. Harper.
Journal of the Association of Engineering Societies,
Vol. XXIV, No. 4, April, 1900, third plate.

ELEVATION.

The figures upon the elevation show the horizontal movements of the dam during the summer of 1899. Those upon the left-hand sides of the posts show the movements as measured, on the top of the posts 14 feet above the crest, from date to date, as given, while the figures on the right indicate the total movement to date.

The figures on the lowest line indicate the total movement at the crest line as measured September 13, 1899.

PLAN.

The figures on the plan indicate the settlement of the aprons at the points indicated, in decimals of a foot, thus:

1. Those nearest the upper left-hand quadrant of the circle, the settlement while the cribs were being filled;

2. Those nearest the upper right-hand quadrant, the settlement between the completion of the filling and the subsidence of the water, and

3. Those nearest the lower half of the circle, the sum of the other two, or the total settlement to September 13, 1899.

The absence of a figure at any of the points designated indicates that the information was not obtained.

… View of Dam and Power House, Looking West.

Deflections of Big Hole Dam. Top of Posts 13 Ft. above Crest. 1st, indicates movement between dates. 2d, total movement to date.

April 14, 10 A.M., 1899									5										10				
" 18, " " "	47	47	46	46	45	45	44	44	43	43	42	42	41	41	42	42	42	42	42	42	43	43	43	43
" 19, " " "	06	53	08	54	07	52	07	51	06	49	06	48	06	47	06	48	06	48	06	48	06	49	05	48
" 20, " " "	02	55	02	56	02	54	02	53	02	51	02	50	02	49	02	50	02	50	02	50	01	50	01	49
" 21, " " "	00	55	00	56	00	54	00	53	00	51	00	50	00	49	01	49	01	49	01	49	00	50	00	49
" 24, " " "	06	61	06	52	06	60	06	59	05	56	05	55	05	54	05	54	05	54	05	54	05	55	05	54
May 7, " " "	09	70	07	69	09	69	09	68	08	64	07	62	06	60	06	60	06	60	06	60	04	59	05	59
" 10, " " "	06	76	08	77	08	77	08	76	08	72	08	70	08	68	07	67	07	67	07	67	08	67	06	65
" 12, " " "	04	80	04	81	04	81	04	80	04	76	04	74	04	72	04	71	04	71	04	71	04	71	04	69
" 21, " " "	05	85	05	86	05	86	05	85	05	81	04	78	03	75	03	74	03	74	03	74	03	74	03	72
" 31, " " "	11	96	10	96	10	96	10	95	10	91	10	88	10	85	09	83	09	83	08	82	07	81	07	79
June 7, " " "	12	1.08	09	1.05	11	1.07	11	1.06	12	1.03	08	96	08	93	08	91	07	90	04	86	07	88	09	88
" 16, " " "	10	1.18	13	1.18	11	1.18	10	1.16	09	1.12	19	1.15	22	1.15	09	1.00	06	96	08	94	07	95	07	95
July 14, " " "	32	1.50	30	1.48	28	1.46	30	1.46	28	1.40	17	1.32	10	1.25	20	1.20	22	1.18	18	1.12	20	1.15	21	1.16
Sept. 13, " " "	02	1.52	00	1.48	00	1.46	00	1.46	00	1.40	00	1.32	01	1.26	02	1.22	00	1.18	03	1.15	00	1.15	00	1.16
Sept. 13, 10 A.M., 1899	1.05		1.08		1.08		1.06		1.02		96		92		89		88		86		82		78	

April 14, 10 A.M., 1899							15										20							
" 18, " " "	41	41	39	39	37	37	34	34	31	31	29	29	27	27	24	24	18	18	12	12	04	04	01	01
" 19, " " "	06	47	05	44	05	42	05	39	05	36	03	32	03	30	02	26	02	20	02	14	01	05	00	01
" 20, " " "	01	48	01	45	01	43	01	40	01	37	01	33	01	31	02	28	01	21	01	15	00	05	00	01
" 21, " " "	00	48	00	45	00	43	00	40	00	37	01	34	00	31	00	28	00	21	00	15	00	05	00	01
" 24, " " "	06	54	05	50	04	47	04	44	05	42	03	37	03	34	02	30	00	23	02	17	01	06	00	01
May 7, " " "	05	59	05	55	05	52	05	49	05	47	05	42	05	39	03	33	03	26	02	19	02	08	00	1
" 10, " " "	06	65	06	61	05	57	05	54	05	52	05	47	04	43	03	36	02	28	01	20	01	09	01	02
" 12, " " "	03	68	03	64	03	60	03	57	03	55	03	50	02	45	02	38	01	29	01	21	01	10	00	02
" 21, " " "	03	71	03	67	03	63	03	60	03	58	03	53	03	18	02	40	01	30	01	22	00	10	00	02
" 31, " " "	05	76	05	72	05	68	05	65	04	62	04	57	04	52	04	44	04	34	03	25	03	13	00	02
June 7, " " "	07	83	09	81	08	76	07	72	06	68	06	63	06	58	06	50	04	38	03	28	01	14	00	02
" 16, " " "	07	90	07	88	07	83	06	78	04	72	07	70	05	63	05	55	03	41	02	30	00	14	00	02
July 14, " " "	20	1.10	20	1.08	15	98	18	96	18	00	15	85	15	78	15	70	11	52	08	38	04	18	00	02
Sept. 13, " " "	00	1.10	02	1.10	00	98	00	96	00	90	00	85	00	78	00	70	00	52	00	38	00	18	00	02
Sept. 13, 10 A.M., 1899	78		76		76		76		70		70		57		52		44		28		15		01	

1899	April 14 Over crest, 200 cu. ft. per sec.
" 18	500
" 19	[illegible]
" 20	[illegible]
" 21	" none.
" 24.	[illegible]
May 7.	[illegible]
" 10.	3600
" 12	[illegible]
" 21	[illegible]
" 31	[illegible]
June 7.	[illegible]
" 16	[illegible]
July 14.	[illegible]
Sept. 13	none.
Sept. 13	Over crest, none

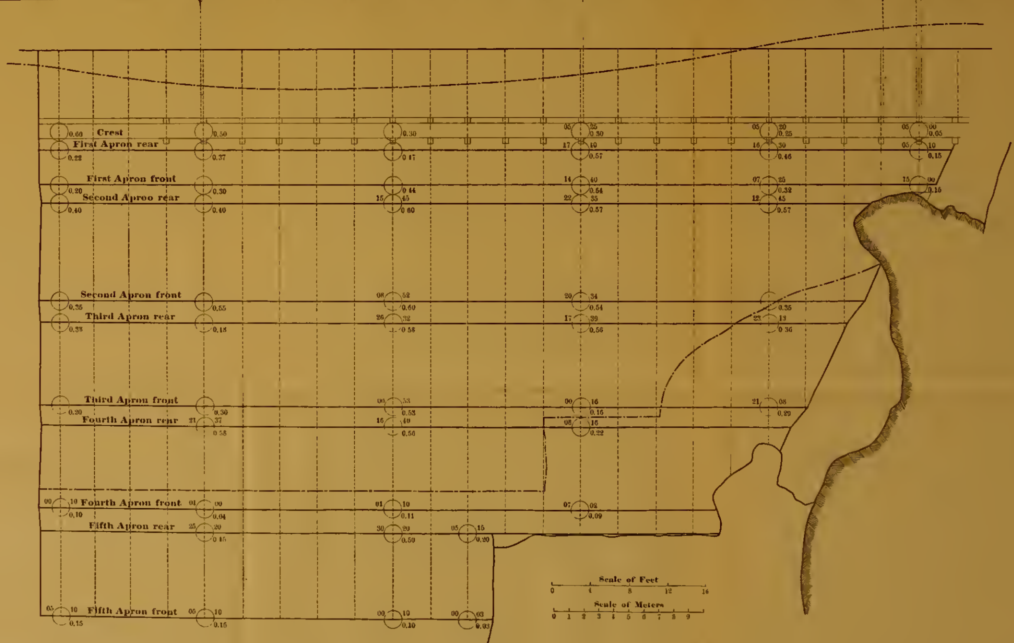


Fig. 6.

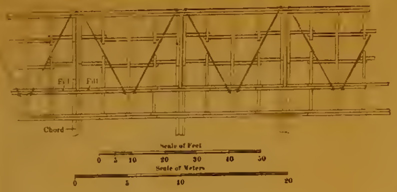


FIG. 4

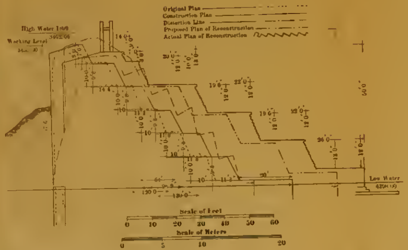


FIG 5

View of Dam and Power House, Looking West.

DEFLECTIONS OF BIG HOLE DAM TOP OF POSTS 13 FT. ABOVE CREST 1D, INDICATES MOVEMENT BETWEEN DATES. 2D, TOTAL MOVEMENT TO DATE

April 14, 10 A.M., 1899.

Date					5					10					15					20				
" 18, " " "	47 47	46 46	45 45	44 44	43 43	42 42	41 41	42 42	42 42	42 42	43 43	43 43	41 41	39 39	37 37	34 34	31 31	29 29	27 27	24 21	18 18	22 22	04 04	01 01
" 19, " " "	06 53	08 54	07 52	07 51	06 49	06 48	06 47	06 48	06 48	06 48	06 49	05 48	06 47	05 44	05 42	05 39	05 36	03 32	03 30	02 26	02 20	02 14	01 05	00 01
" 20, " " "	02 55	02 56	02 54	02 53	02 51	02 50	02 49	02 50	02 50	02 50	01 50	01 49	01 48	01 45	01 43	01 40	01 37	01 33	01 31	02 28	01 21	01 15	00 05	00 01
" 21, " " "	00 55	00 56	00 54	00 53	00 51	00 50	00 49	01 49	01 49	01 49	00 50	00 49	00 48	00 45	00 43	00 40	00 37	01 34	00 31	00 28	00 21	00 15	00 05	00 01
" 24, " " "	06 61	06 62	06 60	06 59	05 56	05 55	05 54	05 54	05 54	05 54	05 55	05 54	06 54	05 50	04 47	04 44	05 42	03 37	03 34	02 30	00 23	02 17	01 00	00 01
May 7, " " "	09 70	07 69	00 69	09 68	08 64	07 62	06 60	06 60	06 60	06 60	04 59	05 59	05 59	05 55	05 52	05 49	05 47	05 42	05 39	03 33	03 26	02 19	02 08	00 01
" 10, " " "	00 76	08 77	08 77	08 76	08 72	08 70	08 68	07 67	07 67	07 67	08 67	06 65	06 65	06 61	05 57	05 54	05 52	05 47	04 43	03 36	02 28	01 20	01 09	01 02
" 12, " " "	04 80	04 81	04 81	04 80	04 76	04 74	04 72	04 71	04 71	04 71	04 71	04 69	03 68	03 64	03 60	03 57	03 55	03 50	02 45	02 38	01 29	01 21	01 10	00 02
" 21, " " "	05 85	05 86	05 86	05 85	05 81	04 78	03 75	03 74	03 74	03 74	03 74	03 72	03 71	03 67	03 63	03 60	03 58	03 53	03 48	02 40	01 30	01 22	00 10	00 02
" 31, " " "	11 96	10 96	10 96	10 95	10 91	10 88	10 85	09 83	09 83	08 82	07 81	07 79	05 76	05 72	05 68	05 65	04 62	04 57	04 52	04 44	04 34	03 25	03 13	00 02
June 7, " " "	12 1.08	09 1.05	11 1.07	11 1.06	12 1.03	68 96	08 93	08 91	07 90	04 86	07 88	09 88	07 83	09 81	08 76	07 72	06 68	06 63	06 58	06 50	04 38	03 28	01 14	00 02
" 16, " " "	10 1.18	13 1.18	11 1.18	10 1.16	09 1.12	19 1.15	22 1.15	09 1.00	06 96	08 94	07 95	07 95	07 90	07 88	07 83	06 78	04 72	07 70	05 63	05 55	03 41	02 30	00 14	00 02
July 14, " " "	32 1.50	30 1.48	28 1.46	30 1.46	28 1.40	17 1.32	10 1.25	20 1.20	22 1.16	18 1.12	20 1.15	21 1.16	20 1.10	20 1.08	15 98	18 96	18 90	15 85	15 78	15 70	11 52	08 38	04 18	00 02
Sept. 13, " " "	02 1.52	00 1.48	00 1.46	00 1.40	00 1.40	00 1.32	01 1.26	02 1.22	00 1.18	03 1.15	00 1.15	00 1.16	00 1.10	02 1.10	00 98	00 96	00 90	00 85	00 78	00 70	00 52	00 38	00 18	00 02
Sept. 13, 10 A.M., 1899	1 05	1 05	1.08	1.06	1.02	96	92	89	88	86	82	78	78	76	76	76	70	70	57	52	44	28	15	01

[illegible] 99.

April 17.	Over crest,	[illegible]
" 18		[illegible]
" 19		[illegible]
" 20		[illegible]
" 21	"	none
" 24.		2
May [illegible]	"	[illegible]
" 10.		360
" 12		[illegible]
" 21		340
" 31		440
June 7		44[illegible]
" [illegible]	"	[illegible]
July 14.	"	[illegible]
Sept 13.	"	none
Sept 13	Over crest, none	

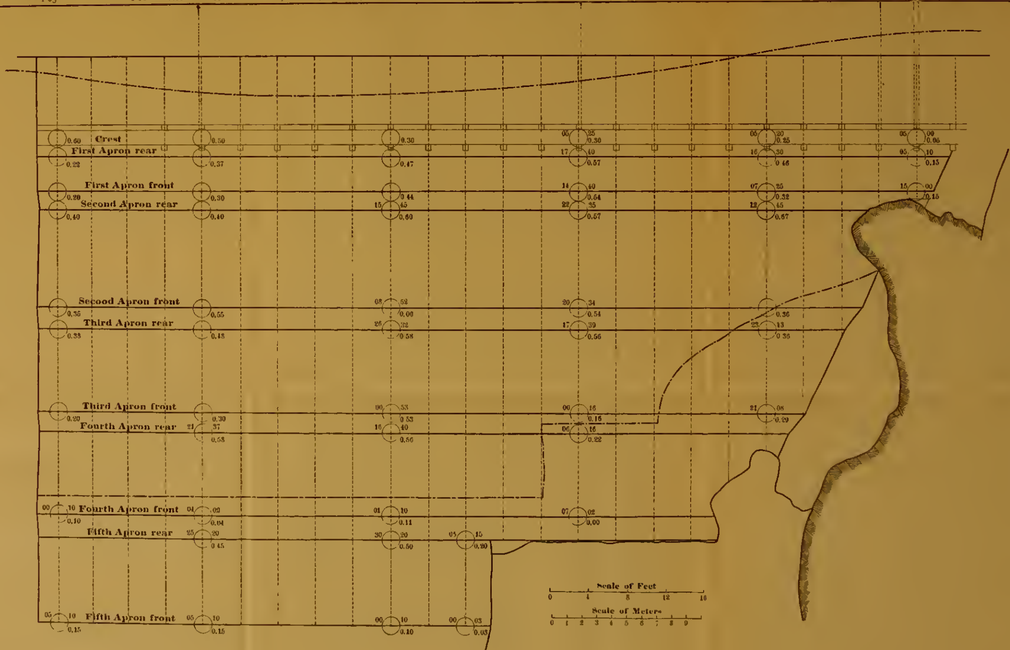


FIG. 6.

ber and area, but I regard it as practical and good construction. It will not matter what form is used upon the overflow, we must in some way prepare to receive the full impact of our maximum flow; and if the ogee be used we must be ready to receive the entire burden at the toe of the dam, and it is often a difficult matter to do this.

MR. HARRISON.—If turned in a horizontal direction it would lessen the damage, would it not?

MR. HARPER.—I think the best method of killing a fall of this kind is found in building a small dam below and submerge the toe of the larger one, thus forming a water cushion to receive the impact. The position of our power house prevented an application of this method with us.

MR. C. D. VAIL.—What was the depth of the water upon the crest?

MR. HARPER.—About 9 feet when measured from the surface of the water in the reservoir. When all needed corrections, since determined, have been made, I find the maximum depth over the lowest point on the crest to have been 9 feet 6 inches.

DRAINAGE OF THE VALLEY AND CITY OF MEXICO.

By Willis B. Wright, Assistant Engineer Drainage Commission of New Orleans, Member of Louisiana Engineering Society.

[Read before the Society March 12, 1900.*]

The City of Mexico was founded by the Aztecs, whose history tells of their migration from the far North, stopping and dwelling many years in three distinct places on the route: first, by the Great Salt Sea in Utah; second, by the Great River in Arizona; third, on plains of Northern Mexico.

Firmly fixed in mind was the legend that their final resting place was to be where they should see an eagle sitting on a cactus killing a snake. This they saw on reaching the Valley of Mexico, on a low, marshy island, far out in the waters of a great lake. There, in accordance with the voice of the oracle, they founded their city, later the seat of a great civilization, and styled by Cortez in his writings, at the time of the conquest, as the most beautiful thing on earth.

It then contained 60,000 houses and 500,000 inhabitants. In the center of the city was a vast pyramid of worship, the summit being reached by a broad road passing four times around the structure in the ascent, and there, often, as many as 20,000 human sacrifices were offered up in the course of a single year.

The Valley of Mexico (see map, Fig. 1) is about 200 miles in circumference, and although 7000 feet above the level of the sea, is entirely surrounded by lofty mountains, of which the snow-clad volcanoes of Popocatepetl, the "Smoking Mountain," and Iztaccihuatl, the "Sleeping Maiden," are 17,000 feet high.

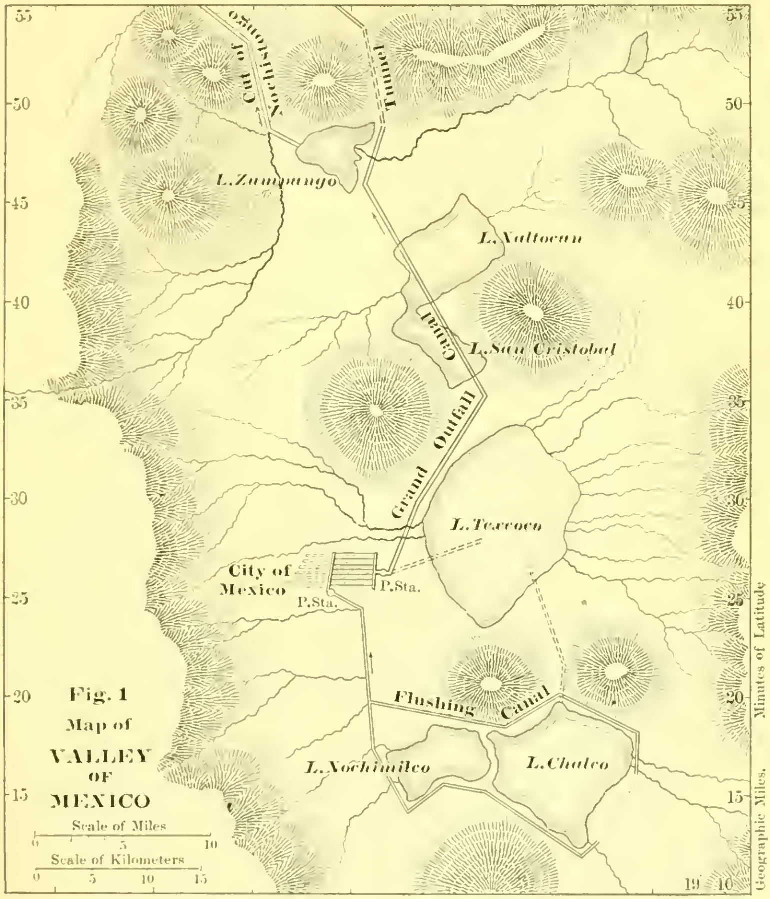
In these mountains rise many rivers, emptying first into a series of lakes, which in turn empty into central Lake Texcoco, the largest and lowest of them all, occupying the extreme bottom of the basin. The City of Mexico, built originally on a low, marshy island in this lake, was intersected by many navigable canals and approached by three causeways, one from the north, one from the west, and one from the south, each three miles long and twenty feet broad.

It can easily be seen that a city situated in the bottom of a basin, and practically on the same level as the water, should be in great danger from floods whenever exceptional rains should occur throughout the valley, and such floods did occur periodically. The inundations, however, did little damage to the natives, who

*Manuscript received April 14, 1900.—Secretary, Ass'n of Eng. Socs.

lived much in canoes and whose houses were so constructed that boats could pass through the lower story.

But the losses occasioned under Spanish rule were very great, and very alarming to the inhabitants, who, after the necessary razing of the old city at the time of the conquest, had abandoned the Aztec system of canals and built a modern city with paved



streets. In the year 1629, the place was flooded to a depth of six feet and so remained for a period of five years. Great wretchedness prevailed, all commerce was at a standstill, and the King of Spain even went so far as to order the city, with its temples and palaces, abandoned for a new site near the foothills. Then, fortunately, a series of earthquakes occurred which opened up fissures in the earth and temporarily swallowed up the waters. More-

over, the shallow lake receded, and left the city on dry land about two miles from the shore, the present condition.

To relieve it from another such catastrophe an opening through the mountains was at length determined upon, to deflect and discharge outside the valley the waters of Lake Zumpango, into which emptied the most important rivers. This work, called the Cut of Nochistongo, was completed in 1789, and was then one of the most gigantic hydraulic operations ever executed by man. The canal through the summit was over twelve miles long, having an extreme depth of 200 feet, and greatest width 360 feet. These operations proved fatal to multitudes of natives, compelled to labor on the public work, carrying out the excavated material in baskets

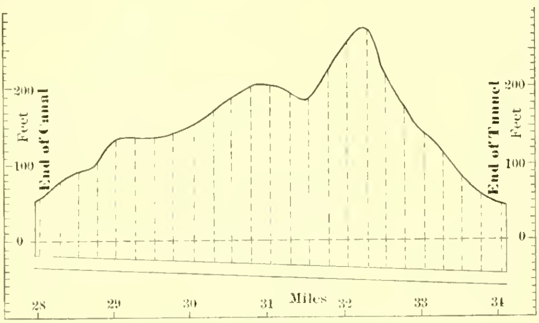


Fig. 2. Profile of Tunnel.

on their heads, and toiling up the steep slopes under pitiless task-masters. In spite of this partial relief the city was still always subject to great risks, and schemes to furnish more perfect drainage were continually advocated.

The new drainage work at last undertaken had in view two objects: first, the complete drainage of the Valley of Mexico, and second, the providing of an outlet for the drainage and sewerage of the City of Mexico.

It had for its key a great tunnel through the mountains. The most serious problem to be solved was the proper location of this tunnel, which was finally decided upon at a point near Lake Zumpango, some miles east of the Cut of Nochistongo. (On Fig. 2 is shown a profile of the tunnel, which is about six miles long, and a cross-section on Fig. 3.)

The tunnel is laid with a broken and increased grade amounting altogether to a fall of 28 feet in six miles. Twenty-five rectangular shafts 8 feet by 10 feet, and varying in depth from 70 to

300 feet, were sunk at regular intervals of one-quarter mile for construction purposes. The tunnel section is egg-shaped, 14 feet in height and slightly less in width. The roof is lined 18 inches thick with four rings or rowlocks of brick. The lower part, somewhat thinner, is lined with artificial stone made of sand and Portland cement. The calculated velocity of flow is about four feet per second, giving a volume of 630 cubic feet per second.

The cutting at the discharge end is about two miles long with an average depth of 50 feet.

The approach canal, called the "Grand Canal" (see profile and sections, Figs. 4 and 5), starts at the City of Mexico near the old pumping station at the gate of San Lazaro, and is about 28 miles long, with a fall amounting altogether to 28 feet, or one foot

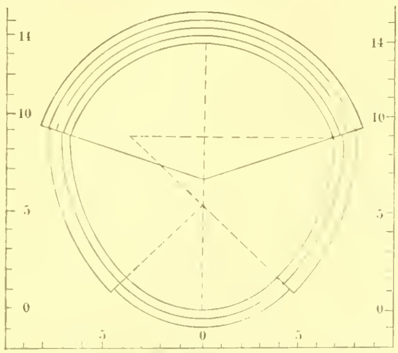


Fig. 3. Section of Tunnel.

per mile. The depth of cutting at San Lazaro is 18 feet, and at the mouth of the tunnel 65 feet. For 12 miles the bottom width is 18 feet, with side slopes of 1 to 1, but from that point on, on account of seepage from the valley, which amounts for several months of the year to as much as 85 cubic feet per second, the bottom width is made 21 feet. It is calculated to carry the maximum amount that can pass through the tunnel,—viz, 630 cubic feet per second.

The soil through which it is built is of clay or calcareous formation. The contractors began work with hand labor, draining by centrifugal pump, reaching thus a depth of 10 feet. Then were used five Couloir dredges of the most powerful class, each capable of excavating 4000 cubic yards per day and discharging the earth at a distance of over 600 feet from the banks of the canal. As they could not work below a certain depth, second cuttings were made by regulating the level of the water in the canal by use of earthen dams. The total excavation reached 15,000,000 cubic

yards, equivalent, at 20,000 cubic yards per day, to 750 working days, or over two years' full time. Every two weeks a special train was at the service of visitors desiring to take a trip of inspection. After the completion of this work the City of Mexico had available the long-desired outlet for the sanitary disposal of its drainage and sewerage.

The old system in use was quite similar to that of New Orleans, but the ground being quite level the city did not have even the advantage of the fall we have from the river toward the lake. The gutters were not open as here, but were carried under the pavement. The catch basins were usually merely two narrow slits in the stone covering. The drains being nearly level, only a very sluggish flow could be obtained at times when there was much rain. During the dry season many were practically stagnant, and offen-

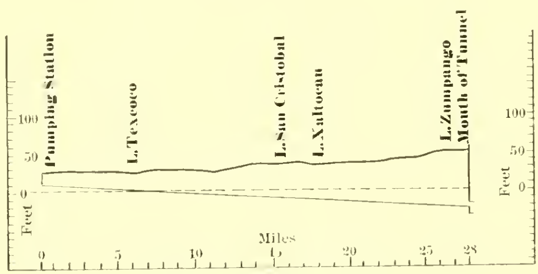


Fig. 4. Profile of Canal.

sive at openings, in spite of such flushing as could be obtained by gravity from the Viga Canal. Many closets of modern design were connected with these drains, which for lack of current gradually filled and became absolutely choked with solid matter. When so filled the pavement had to be torn up, and the contents excavated, and the nuisance thus created was unspeakable. During heavy rains the streets were flooded and impassable, just as they are, or rather used to be, here. All drains finally emptied into an open low-level canal running to the gate of San Lazaro. There was located a pumping station which discharged through an open high-level canal into Lake Texcoco. This tended continually to fill up the lake, already too shallow, and created very unsanitary conditions, much worse than at Lake Pontchartrain, where the water is deeper.

Like all Spanish cities, Mexico has narrow streets and is compactly built, nearly all the houses being contiguous. With a population of 300,000 souls, being somewhat more than that of New Orleans, it stands on a tract of land only a little more than two

miles square, as compared with about twenty square miles of built up area here.

A new drainage and sewerage system designed for the city proper has been contracted for and partially constructed. It is the combined water carriage system, and not the separate system as in use here, the comparatively small area served and small rainfall rendering this possible and advisable.

As with our own drainage system, three years of careful preparation were spent before the system was finally adopted. A comparative study was made of the methods in use in all the larger cities of both Europe and the United States. All the problems to be met with were considered and solved, by analyzing not only the conditions under which each solution was arrived at, but also the defects and difficulties which had been observed in each case after completion.

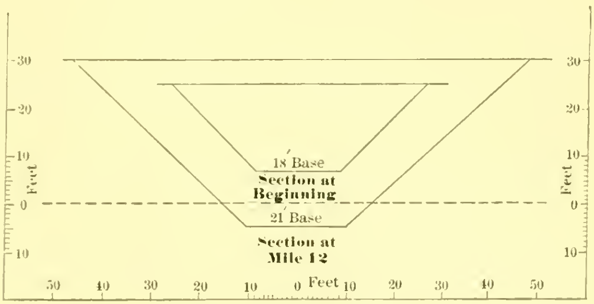


Fig. 5. Sections of Canal.

The scheme approved satisfied this prime condition, that any sanitary work should be simple, both as to whole and to details; also that nothing should be done that is not absolutely indispensable.

A new discharge pumping station with ordinary discharge duty of 175 cubic feet per second is located at the eastern edge of the city, near the old site at the gate of San Lazaro, at the beginning of the Grand Canal. North and south from this station run the main receiving sewers, each 8 feet in diameter and 1 mile long. From these, westward, at right angles, on selected streets six blocks apart, run six trunk or collecting sewers, each 6 feet in diameter and 2 miles long. These collect the sewerage from laterals of vitrified pipe, from 24 inches to 16 inches in diameter, running zigzag for three blocks each way to summits. Thus laterals run along every street and reach every corner, avoiding all dead ends except on summit streets.

The flushing system is thus arranged. Some miles to the southward are the Lakes Xochimilco and Chalco, of area about 50 square miles, and some feet above the level of the city. A canal is located, encircling these lakes, so as to collect all the water of the streams flowing into them. Thence, intercepting other streams on the way, it reaches the city at the southwestern corner, near the

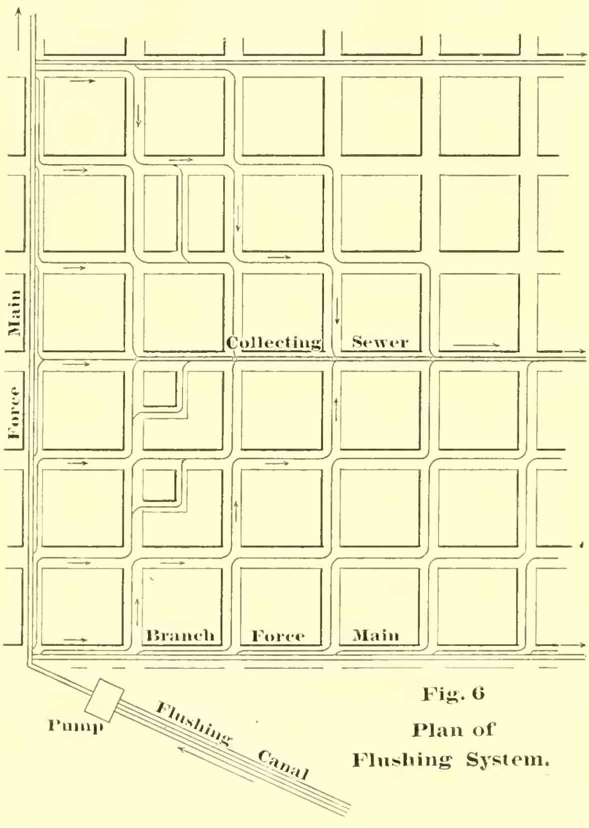


Fig. 6
Plan of
Flushing System.

Piedad gate. There a pumping station is located with a pump capable of discharging 35 cubic feet per second, with a pressure of 15 pounds per square inch. This pump furnishes water to a steel force main 42 inches in diameter, running north along the western side of the city, opposite the discharge pumping station (see Fig. 6). From this main, at intervals of six blocks, at right angles, along the summit streets, run steel branch pipes 30 inches in diameter, and to these pipes with valve connections all the ends of the lateral sewers are joined for flushing.

With a pump capacity of 200 cubic feet per second, it would be possible to establish a constant current that would never be less than 2 feet per second, through all the sewers of the city.

With only a part of the water furnished by the flushing canal it would be possible to flush every day all the sewers of the city by sudden rushes of water, giving a least velocity of 3 to 6 feet per second.

It is certain that flushing as often as once a day will not be necessary, but even so, it would only require the continuous service of a small number of men at moderate wages.

Up to the present time it is said that there is no city in the world that can be so well and cheaply served.

All main sewers are circular and made of press-hardened brick, with mortar of cement and hydraulic lime. The bottom is treated with a cement coating to give a smooth surface.

The flushing mains are of riveted steel, about 3-16 inches in thickness, and are treated with a preparation of asphaltum, said, as shown by experience, to preserve them from rust indefinitely.

The laterals are of ordinary vitrified pipe.

All connections and bifurcations are made with necessary precautions. Increased slope is used in curves.

Careful study was made of gutter connections so as to prevent the entrance of street rubbish. Provision is made to remove obstacles, should they by any possibility be encountered, by constructing plenty of manholes and lampholes, to save removal of pavement. In accordance with the absolute general principle, all drains are thoroughly ventilated.

With all these precautions to avoid silting up, it is not probable that any dangerous closures will occur, or that any pestilential odors will be emitted.

The City of Mexico is spreading westward toward Chapultepec, and the system designed, although referring herein only to the old city, is planned for extension to take in an equal area of suburban district to provide for future growth, as has been done here with our own drainage system. Of course such a perfect system of drainage and sewerage to a city so situated will be of inestimable value.

Being in the Federal District, the work is carried out largely at the expense of the National Government, which in all countries has means of collecting ample funds for such great improvements.

How much greater the credit to this city which to-day is taking upon its shoulders unassisted the burden of providing for so much greater area, separate, and therefore more costly, systems of drainage and sewerage, as well as a modern system of water works.

THE CEMENT AGE.

By G. W. Percy, Member Technical Society of the Pacific Coast.

[Read before the Society April 6, 1900.*]

From a very early period in the history of building, mankind in every part of the world has sought a proper material for binding together the separate bricks, stones or fragments with which he constructed his walls.

The qualities and properties such material should possess are obviously:—

First. That when prepared for use it should be soft and plastic to properly fill all joints, cavities and interstices between the larger members.

Second. That it should harden and resist decomposition on exposure to the air and other elements.

Third. That it should have a good degree of adhesive and cohesive strength, and, lastly, that it should be readily obtained in abundant quantities.

As civilization advanced, and more important works were undertaken, not only on dry land but in water, another important property was required,—namely, that such material should set or harden under water, and be able to resist the actions of that element even when subject to strong currents, or sea waves.

The progress toward attaining the desired results has often been slow and groping. At times rapid strides were made, while at other times for entire centuries the art seems to have retrograded.

Most primitive peoples seem to have commenced with clay, used in its natural state.

As its defects became apparent, they improved it in some cases by mixing with sand, gravel or with crushed shells, and in other cases with straw and other fibrous materials.

In some parts of the world where bitumen could be obtained it was used very successfully for cementing bricks and stone together, as at Babylon; and the "slime" referred to in Gen. xl. 3 was doubtless bitumen. On account of its common use, the ruins of Babylon are much better preserved than those of Ninevah, which appears to have been built largely of adobe bricks and loamy mortar.

When and where the discovery was first made that marble or other pure limestone, when burned or calcined with great heat,

*Manuscript received April 12, 1900.—Secretary, Ass'n of Eng. Socs.

slaked with water and mixed with sand or fine gravel, would make a good cementing substance is not known.

But its discovery was one of the great strides toward better building and higher civilization.

It can be traced back to the ancient Phœnicians and Egyptians, whose massive ruins to this day show clearly its use.

The Greeks, to whom we naturally look for improvement over all earlier artificers, instead of developing a cementing substance, sought to dispense with it entirely by making such perfect joints in their stone structures as to leave no room for cement or mortar of any kind, and the prodigious labor they expended and the high mechanical skill they employed in rubbing massive stones to perfect joints and inserting dowels or keys of wood and metal has remained the wonder of the world.

To the ancient Romans we must look, not only for the greatest perfections in this art, but for the earliest literature on the subject that has come down to us.

Vitruvius, in his ten books on architecture, written about twenty-five years before the Christian Era, has much to say on the subject of lime, mortar, cement, etc.

As the exact process of setting and hardening of mortar is not fully understood in our day, it may be interesting to note how glibly Vitruvius (with whom everything in nature is composed of four elements,—earth, air, fire and water) explains the mystery.

He says: "Of the nature of lime, which is burnt, either from white stone or flint, that which is of a close and hard texture is better for building walls; as that which is more porous is better for plastering.

"When slaked for making mortar, if pit sand be used, three parts of sand are mixed with one of lime; if river or sea sand be made use of, two parts of sand are given to one of lime, which will be found a proper proportion. . . . .

"The cause of the mass becoming solid when sand and water are added to the lime appears to be that stones, like other bodies, are a compound of elements; those which contain large quantities of air being soft; those which have a great proportion of water being tough, of earth hard, of fire brittle. For stones which when burnt would make excellent lime, if pounded and mixed with sand, without burning, would neither bind the work together nor set hard; but having passed through the kiln and having lost the property of their former tenacity by the action of intense heat, their adhesiveness being exhausted, the pores are left open and inactive. The moisture and air which were in the body of the stone having

therefore been extracted and exhausted, the heat being partially retained, when the substance is immersed in water, before the heat can be dissipated, it acquires strength by the water rushing into all its pores, effervesces, and at last the heat is excluded.

"Hence, limestone, previous to its burning, is much heavier than it is after having passed through the kiln; for, though equal in bulk, it is known by abstraction of the moisture it previously contained to lose one-third of its weight by the process.

"The pores of limestone being thus opened, it more easily takes up the sand mixed with it, and adheres thereto; and hence in drying binds the stones together, by which sound work is obtained."

The Romans probably gave more attention to the selection of good material and careful manipulation in making mortar than any other people.

Pliny tells us that "lime was not allowed to be used until it had been slaked for a period of three years."

The sand and prepared lime were then pounded in the "mortarium" and converted into a cement; our word mortar being derived from the vessel, which we still call a mortar, but no longer use for that purpose.

The early Romans also discovered that the addition of pozzuolana from the volcanic ashes, when properly mixed with the lime mortar, gave to it hydraulic properties and enabled them to successfully execute such engineering work as piers, harbors, aqueducts, great cisterns, etc.

Of this material Vitruvius says:

"There is a species of sand which naturally possesses extraordinary qualities.

"It is found about Bäiae and the territory in the neighborhood of Mount Vesuvius; if mixed with lime and rubble, it hardens as well under water as in ordinary buildings."

He explains this as follows:

"This seems to arise from the hotness of the earth under these mountains, and the abundance of springs under their bases which are heated either with sulphur, bitumen or alum, and indicate very intense fire. The inward fire and heat of the flame which escapes and burns through the chinks make this earth light; the sandstone, therefore, which is gathered in the neighborhood is dry and free from moisture.

"Since, then, three circumstances of a similar nature, arising from the intensity of the fire, combine in one mixture as soon as moisture supervenes, they cohere and quickly harden through

dampness, so that neither the waves nor the force of the water can disunite them."

His next sentence is an interesting reference to the condition of Vesuvius and the traditions prevailing in his day, one hundred years before the great eruptions which destroyed Pompeii and Herculaneum. He says:

"That these lands are affected with heat, as surmised, is evident, because in the mountains of Cunea and at Bäiae sweating places are excavated in which the hot vapor, rising upward from the intensity of the fire, strikes through the earth, and so escapes in these places that they are singularly beneficial for the purposes described.

"It is, moreover, said that in former times fires under Vesuvius existed in abundance, and thence evolved flames about the fields."

The use of pozzuolana by the Romans to improve lime mortar and to impart some hydraulic property was the first step so far as known toward a pure hydraulic mortar or cement.

The Romans used it in all their important structures in Italy, and where pozzuolana could not be obtained they sought some substitute; as on the Rhine they used pounded tufa or trass; in Britain and France they often used pulverized bricks and pottery, nearly always producing an excellent mortar.

After the downfall of the Roman power, and throughout the middle ages, no improvement whatever was made in the art, and less care bestowed in selecting and manipulating the ingredients. As a result, for twelve hundred years mortar inferior to that of the Romans was generally used, and making good hydraulic mortar was a lost art.

During the eighteenth century, much attention was given to the subject and many attempts were made to improve lime mortar by the use of pozzuolana as described by Vitruvius, but without very marked success.

It was not until the year 1756 that John Smeaton, the celebrated engineer, in experimenting to find a suitable mortar with which to erect the Eddystone Lighthouse, discovered the true source of hydraulicity in certain limestones.

He made many experiments with pure lime mixed with pozzuolana and with powdered bricks, without obtaining satisfactory results. But on trying lime made from the impure limestone of "Aberthaw" he found it to be fairly hydraulic.

On carrying the experiment farther with other impure limestones, he arrived at and announced his conclusions that only lime-

stones carrying clay or argillaceous earth had hydraulic properties.

Of this discovery Smeaton in his "Narrative of the Eddystone Lighthouse" says:

"It remains a curious question which I must leave to learned naturalists and chemists, why an intermediate mixture of clay in the compositions of limestone of any kind, either hard or soft, should render it capable of setting in water in a manner no pure lime I have yet seen, from any kind of stone whatever, has been capable of doing.

"It is easy to add clay in any proportion to pure lime, but it produces no such effect; it is easy to add brick dust either finely or coarsely powdered to such lime in any proportions also; but this seems unattended with any other effect than what arises from other bodies, becoming porous and spongy and therefore absorbent of water as already hinted and excepting what may reasonably be attributed to the irony particles that red brick dust may contain.

"In short, I have as yet found no treatment of pure calcareous lime that renders it more fit to set in water than it is by nature, except what is to be derived from the admixture of trass, pozzuolana and some ferruginous substance of a similar nature."

The mortar used by Smeaton in erecting the Eddystone Lighthouse was carefully composed of Aberthaw hydraulic lime and Italian pozzuolana, and the investigations commenced by Smeaton were followed up until near the middle of this century. They resulted in the manufacture of Portland cement.

Smeaton's own experiments, which resulted in one great discovery, just fell short of a greater one.

He found in the quarries of Aberthaw limestone, various stratas, all carrying more or less clay, and selected only such as would slake in water, after being burnt, rejecting all that would not slake.

Had he burnt some of this rejected limestone more thoroughly and ground it to a fine powder, he would have discovered the secret of the rock cements of our day, and obtained a superior article for his important engineering work.

The latter discovery seems to rest with Mr. Parker, of London, who, in the year 1796, took out a patent for the manufacture of what he called "Roman Cement" from nodules of clay and limestone formation found in the Isle Sheppy and along certain parts of the Kent and Essex coasts.

These nodules were of natural cement rock and after calcinations it was reduced to powder in mills suited to the purpose, producing a very strong, quick-setting, hydraulic cement, which soon caused great demand both in England and for export.

At one time Roman cement was considered an article of sufficient importance to require special legislation in the English Parliament for its protection.

During the premiership of Sir Robert Peel, serious intentions were entertained of imposing a prohibitory tax on all foreigners found dredging for cement stone off the English coast.

In 1818,—twenty-two years after Parker had patented his Roman cement,—Canvass White, of this country, discovered and patented a similar cement found near Fayetteville, N. Y.

The cement was used in large quantities in the construction of locks, viaducts and culverts on the Erie Canal, then in course of construction.

Subsequently the State of New York purchased the patent from Mr. White for $10,000 and made the discovery public property.

This proved to be the beginning of a great industry, not only of the well-known Rosendale cement in New York, but in many other sections of the country where suitable materials are found.

At this date the production of natural rock cements in the United States amounts to about 9,000,000 barrels yearly.

The first mention we have of the production of an artificial cement or of "Artificial Hydraulic Lime," as it was then called, was in 1810, when Edgar Dobbs, of Southwark, London, obtained a patent for its manufacture by mixing in suitable proportions carbonate of lime and clay, and after drying he molded or cut it into pieces before burning.

He then states that:

"The burning must be sufficient to expel the carbonic acid from the lime without vitrifying any of the substances."

Artificial hydraulic lime was also produced in France and Russia between 1813 and 1818.

In 1824, Joseph Aspdin, of Leeds, England, obtained a patent for the manufacture of an artificial cement which in his specifications he calls "Portland Cement," the first time the word Portland was applied to a cement, and was given by Aspdin because of the similarity in color of his cement to the well-known and popular building stone known as Portland stone.

Mr. Aspdin's specifications, acompanying his application for a patent, are as follows:

"My method of making a cement or artificial stone for stuccoing buildings, water tanks, cisterns, or any other purpose to which it may be applicable (and which I call Portland cement), is as follows:

"I take a specific quantity of limestone, such as that generally used in making or repairing roads, and I take it from the roads after it is reduced to a puddle, or powder; but if I cannot procure a sufficient quantity of the above from the roads, I obtain the limestone itself and I cause the puddle or powder or the limestone, as the case may be, to be calcined, and I then take a specific quantity of argillaceous earth or clay and mix them with water to a state approaching impalpability either by manual labor or machinery.

"After this proceeding, I put the above mixture into a slip pan for evaporation, either by heat of the sun or by submitting it to the action of fire, or steam conveyed in flue pipes under or near the pan, until the water is entirely evaporated.

"Then I break up said mixture into suitable lumps and calcine them in a furnace similar to a limekiln, until the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beaten or rolled to a fine powder, and is then in a fit state for making cement or artificial stone.

"This powder is to be mixed with sufficient quantity of water to bring it into the consistency of mortar and thus applied to the purposes wanted."

This patent of Aspdin's proved of little importance at the time. Little or no manufacturing appears to have been done under it, and it is of little interest aside from the fact that it gave a name to the material now so extensively manufactured and universally used in important engineering and architectural works.

Scientific investigators, notably among whom were Dr. John, of Berlin, M. Vicot, of France, and General Pasley, of England, were diligently at work from 1818 to 1850 in perfecting this desirable material.

The first successful establishment to manufacture and sell Portland cement was by J. B. White & Sons, England, in 1845.

The investigations and discovery of Smeaton that clay in the limestone imparted hydraulicity, together with the analysis of many specimens of cement and mortar from Roman ruins, all showing a large proportion of silicate and alumina, led the investigators to experiment with lime, silica and alumina in various proportions and with various degrees of success.

It was not until 1850 that an artificial cement was produced that could successfully compete with the Roman and other natural rock cement.

It having been proven that a mixture containing about 60 per cent. carbonate of lime, about 25 per cent. of silica and about 15 per cent. of alumina and iron oxides would, when properly mixed, thoroughly burnt and ground to a fine powder, produce a uniform, quick-setting and very strong hydraulic cement; factories were established on the Thames and Medway Rivers for its production, where the raw materials were found in abundance, the chalk formations furnishing the pure carbonate of lime, and the clay sediment of the rivers, composed principally of silica and alumina with some oxide of iron, traces of magnesia and other impurities not in sufficient quantities to injure the cement.

The early manufactures used, roughly, 2½ parts of chalk to 1 of clay.

The process of manufacture consists in mixing the chalk and clay in wash mills with sufficient water to reduce it to a creamy consistence. This is known as slurry, and is dried in shallow receptacles, heated by the waste heat from the furnaces and kilns.

It is then burned at a fixed temperature to the point of incipient vitrification, somewhat resembling pumice stone, and to which the name of clinker is applied.

The clinker, being ground to the finest powder and bolted through fine sieves, furnished the finished product known the world over as Portland cement.

The superiority of Portland cement over Parker's Roman cement was not fully established in England until about 1860, and soon after that date the product was very greatly increased and importations were made to this country, selling in New York in 1865 at $8.00 to $10.00 per barrel.

To show the conservatism of the English Government toward advanced ideas, as late as 1867,—forty-three years after Portland cement was invented and patented,—a large contract for Chatham Dockyard was let by the Admiralty, and while the work to be executed was within a few hundred yards of two Portland cement factories, that material was not mentioned in the specifications; but Roman cement and pozzuolana was called for in all work below the water line.

This was found very unsatisfactory, and during the progress of the work, Portland cement was substituted.

It was found that one-half the quantity of Portland cement made much better and stronger work.

The first Portland cement brought to San Francisco was in 1862, and it could not be sold at cost price.

Builders condemned it on inspection, as the color was different from Roman or other natural cements to which they were accustomed. After being kept for two years it was sold for warehouse charges, and purchased by Robert Mitchell, who used it in sewer building, where its superiority soon became manifested.

At that time Roman cement sold in San Francisco at $9.00 per barrel, and Benicia, a local natural cement then on the market, at $7.00 per barrel.

Soon after 1870 the importation of Portland cement increased largely and the price was greatly reduced.

In December, 1873, the first cement sidewalk on the Pacific Coast was laid by George Goodman (who is still in that business) on the northwest corner of California and Kearney streets, San Francisco.* At that time Portland cement sold at $6.50 per barrel.

For the past twenty-five years the manufacture and consumption of Portland cement has increased with astonishing rapidity, and by its aid many important engineering works have been successfully executed, which without it would be almost impossible.

It is now used in all civilized countries as the cementing material, not only in brick and stone masonry, but mixed as concrete with sand, gravel and crushed stones as the basis of all good street paving, sidewalks, basement floors, piers and abutments for bridges, foundations of heavy structures of all kinds, sea walls, breakwater docks and harbor works, dams and reservoirs.

It is molded into blocks for artificial stone and ornaments, spread as stucco on the face of rough brick and stone work. It is applied to the steel frames of ships to prevent corrosion and to the steel skeletons of buildings to prevent both corrosion and the effects of fire.

Its uses seem to be constantly multiplying, and it has never been driven from a field once occupied.

The rapid development of its use in this country may be inferred from the following abbreviated table of imports:

Imports,	1870,	about	35,000	barrels.
"	1880,	"	300,000	"
"	1885,	"	550,000	"
"	1890,	"	1,940,000	"
"	1891,	"	2,988,000	"

1891 and 1892 reached the high-water mark of importation. The following three or four years showed a falling off owing to

*This first piece of sidewalk, after twenty-six years of wear, and while still in excellent condition, was removed a few months ago on account of rebuilding on the premises.

the business depression, while the great increase in home production has more than supplied the increased demand during the last three or four years.

The first American Portland cement was manufactured by the Copley Cement Co., in Pennsylvania, in 1875 to the extent of 1700 barrels. In 1880 this company manufactured and sold 32,000 barrels. Their output steadily increased until 1890 it reached 100,000 barrels. In the meantime several other manufacturers were in the field, making the entire American product in 1890 about 335,000 barrels.

This was increased with most astonishing rapidity, as the following table shows:

1894,	about	800,000	barrels.
1896,	"	1,550,000	"
1897,	"	2,678,000	"
1898,	"	3,700,000	"
1899,	over	4,000,000	"

While this enormous growth of the production of Portland cement in this country has been going on, that of natural rock cement has progressed with equal strides.

Its quality has been improved and more uniform results obtained by a careful selection of materials, and as it can be manufactured and sold at less than half the price of Portland cement it is extensively used, as the returns show about 9,000,000 barrels produced yearly in this country.

Thus we may place the consumption of hydraulic cement in the United States for the year 1899 at something over 15,000,000 barrels, 9,000,000 of natural and over 6,000,000 of Portland cement, of which all but 2,100,000 barrels was home production.

As before stated, the first factories of Portland cement were established in England, and soon after 1860 English Portland cement commenced to be used in this country on the most important works as well as in other parts of the world.

For about fifteen years after 1860 all the Portland cement used in the United States came from England.

That manufactured by White & Sons and by Knight, Beven & Sturges was considerd the best and standard.

In the meantime the Germans had commenced its manufacture, and by the application of better scientific knowledge and skill they produced an article superior to the English and about 1875 invaded the American market.

Up to that time it had been considered that the weight of Portland cement was a fair index of its quality, that which weighed the heaviest being considered the best.

As better results in weight could be obtained by not grinding it all to an impalpable powder, the English cements contained a large proportion of coarser grains; about 10 per cent. would be left on a sieve of 2500 meshes to a square inch, and 25 to 30 per cent. on a sieve of 10,000 meshes to a square inch.

The Germans, however, demonstrated that fineness was of more importance than weight, and from the first ground their cement finer than the English and produced far better results.

The correctness of the claim was easily shown in the following manner.

By sifting out the coarser grains from the English cement and mixing them with water, it would not set or harden any more than so much sand, but these same coarse grains when ground or pounded to an impalpable powder would prove to be the best cement in the entire lot.

Notwithstanding such easy demonstrations of incompleteness in the English method of manufacture, it was several years before they could be induced to change their method of grinding, and not until they had lost the best of their foreign markets.

Of the 2,103,000 barrels imported into the United States during 1899—

1,200,000	barrels came from Germany.
620,000	barrels from Belgium.
200,000	or 1-10 from England.
13,000	barrels from France.
70,000	barrels from other countries.
2,103,000	

From the very crude method of judging the strength of Portland cement by its weight, so commonly practiced twenty-five years ago, a very elaborate system of mechanical and chemical testing has been developed, and an exceedingly high standard of excellence established.

A first-class brand of Portland cement must be composed of the proper ingredients in exact proportions. It must be thoroughly and uniformly burnt to a hard clinker. It must be so finely ground that all or nearly all will pass through a sieve of 10,000 meshes to a square inch. It must, when mixed with water and formed into briquettes, require about 500 to 600 pounds to a square inch to tear it asunder when one week old, and about 700 to 800 pounds when one month old, while it should continue to increase in strength with diminishing rates for about two years.

It must contain no free lime, not over 1½ per cent. of magnesia and no other substance that under any known conditions could contribute to its disintegration.

Thus we have in Portland cement the most enduring material produced and used by man on an extensive scale in all his constructive arts.

The most important and lasting monuments of modern times owe to this remarkable material much of their integrity and enduring quality.

Ethnologists inform us that the earliest age of man was one in which his principal works were of clay, then an age of stone in the rough and later polished state, then an age of bronze, then iron, while the present is often called the age of steel.

If, however, we could imagine a great cataclysm of nature to occur during the coming century, which should effectually remove all civilized peoples from the face of the earth, wipe out all their literature and knowledge, leaving their works, both monumental and industrial, to the destroying hand of time and the acts of barbarous peoples for one or two thousand years, and then with a dawning civilization another race of ethnologists should arise and attempt to classify the ruins of our age, they would doubtless call our stage of development the "Cement Age."

Notwithstanding the fact that 35,000,000 tons of iron and steel are produced and used annually, very little would be found after two millenniums of barbarity and desolation.

The many millions of tons now afloat of vessels of commerce and war would be completely dissolved and hopelessly dispersed in the waters of the oceans. Other millions of tons now used as rails binding towns, cities and nations together could only be discovered by occasional traces of brown oxide.

While if in occasional structures of masonry, iron and steel might be protected from the elements, it would only be where deeply embedded in cement, and in such places the people of that dawning civilization would seek it for use in their rude arts.

And by that very seeking they would become familiar with the vast works of our race.

Great piers would be found where bridges once crossed the waters, masses once serving as dams would stand above the plains where adjoining hills had crumbled and washed away.

Great basins now serving as docks would suggest bath tubs of a giant race, while great ribbons of concrete many miles in extent, interlacing between massive foundations of cement, would reveal to the explorer the site of a cement city; and if by chance one stone was found upon another it would be because it was held in the firm grip of hydraulic cement.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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DIFFICULTIES ENCOUNTERED IN BUILDING THE STORAGE WELL FOR THE SEWERAGE SYSTEM OF CONCORD, MASSACHUSETTS.

BY LEONARD METCALF, ASSOCIATE MEMBER AMERICAN SOCIETY CIVIL ENGINEERS, MEMBER BOSTON SOCIETY CIVIL ENGINEERS.

[Presented before the Boston Society of Civil Engineers April 18, 1900. Illustrated by stereopticon views.*]

IN the spring of the year 1898 the town of Concord, Mass., undertook the construction of a sewerage system for the central portion of the town. Plans were prepared by the writer for a system comprising the building of 6½ miles of pipe sewers, a storage well, a power station which was to provide room for the municipal lighting plant as well as for the sewage pumping plant, one mile of 10-inch cast iron force main, and 3.3 acres of sand filtration beds upon which to dispose of the sewage.

The amount of sewage to be pumped was estimated at 240,000 gallons per twenty-four hours under normal conditions. For economy in operation, the capacity of this well and the pumps was made such that the pumping would be confined to the hours of running the municipal lighting plant, thus requiring no additional attendance and reducing the cost of operation. The sewage pump was to be run by steam furnished by the municipal light plant boilers, at times of light load upon the dynamos—in the early afternoon and late night hours—discontinuing pumping when the light load was heaviest—in the early evening hours—and thus equalizing the work of the boilers. The plan also provided that later, when Concord Junction should be connected with the

*Manuscript received March 29, 1900.—Secretary, Ass'n of Eng. Socs.

system, an additional storage well should be built there, to store the day flow and let it down into the Concord storage well during the night, when the sewage discharge was a minimum and the pumps were operating.

The storage well was located on the meadows near the Boston and Maine Railroad tracks, between Lowell Road and the Sudbury River, and about 650 feet from the latter. This meadow lies within the valley of the river, but 5 feet above the level of mean low water, and is submerged by the spring freshets to a depth of 1 or 2 feet, and in extreme cases to a depth of 5 or 6 feet.

The conditions governing the location of the well were as follows: (1) Low elevation, that the amount of excavation necessary to obtain storage capacity below the point of discharge of the trunk sewers leading to it, and hence the cost thereof, should be as small as possible; (2) Central location, that the length and hence the cost of the sewers discharging into it and laid in deep cut should be as small as possible; (3) Proximity to the power station, on account of the sewage pumping machinery located therein; (4) Proximity to a railroad, on account of sidetrack for coal for the power station; (5) Proximity to the river, on account of the necessity for large quantities of water for the municipal light plant condenser; (6) Proximity to the filter beds, that the amount and cost of the cast iron force main required should be as small as possible; and (7) Remoteness from dwellings, on account of sentimental considerations.

A test-pit was dug on the site of the storage well to a depth of about 10 feet, and iron pipes were driven down in this excavation to the depth of the foundations, to show the character of the material to be encountered, and to enable bidders to figure intelligently upon this structure, which bade fair to offer some difficulty in construction. It is interesting at this time to recall the fact that several contractors who had contemplated bidding on the work refused to do so when they saw the nature of the material in which this well was to be built.

The original design for the storage well contemplated a circular well 60 feet in internal diameter, 23 feet in depth to bottom of foundations, with 24-inch brick walls, inverted segmental groined arch bottom of concrete, laid upon a timber foundation; elliptical groined arch roof of concrete supported on 24-inch brick piers, 15½ feet on centers, with a small screen chamber on the side similar to a manhole, into which the two sewers were to discharge and from which the pump was to draft its supply. The capacity of the well, up to Grade 97, or 3 feet below low water in the

river, was about 250,000 gallons. Manholes were also provided in the roof, for access to the inside of the well, and an 18-inch vent pipe leading to the boiler furnaces, with by-pass in the chimney.

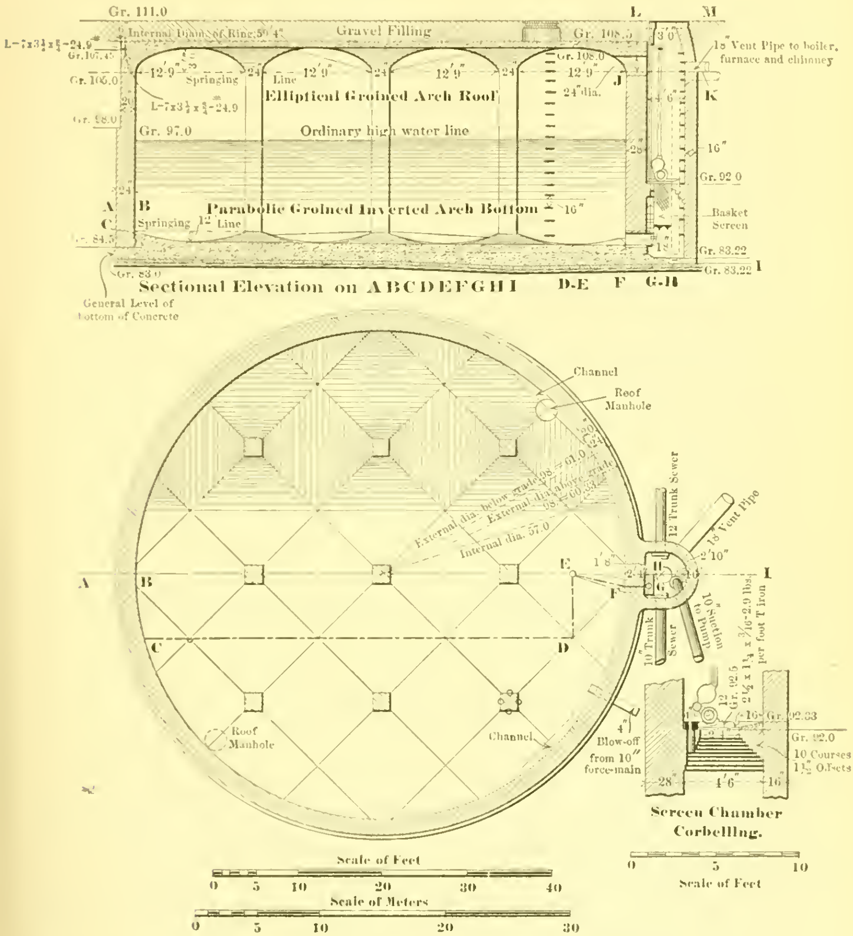


FIG. 1. STORAGE WELL AND SCREEN CHAMBER.

Storage Capacity, Gr. 84.8 to 97.0 = 29,675 cu. ft. = 222,000 U. S. gallons.
Emergency " " 84.8 " 105.0 = 49,953 " " = 373,000 " "
Capacity per foot of depth = 2,535 " " = 19,000 " "
Net area Storage Well = 2,515.8 sq. ft.
" " Screen Chamber = 19.2 " "
Mean level of bottom = Gr. 85.3

Pier load.—Gravel @ 100 lbs. per cu. ft = 54,390 lbs.
Snow @ 15 " " " " = 3.263 "
Roof concrete 200.3 cu. ft. @ 155 lbs. = 31,047 "
Brick Piers Gr. 85 to Gr. 105 @ 125 lbs. = 10,000 "

97,700 "
= 24,675 " per sq. ft
= 12.3 tons per sq. ft.

The construction of the storage well was included in the general contract for building the sewerage system awarded to Messrs. T. W. Kinser & Sons, of Boston.

While bidders were at liberty to conduct the work in such manner as they chose, the following method of construction was suggested to them: the driving of a series of wells around the exterior of a line of splined and grooved sheeting surrounding the storage well, and the pumping down of the ground water-level or table to a plane below the foundation of the well. This method was perhaps unique only in the form of driven well required. The ordinary driven well could not be used, as the material was too fine for the finest screen and the amount of water too small. Hence it was suggested that the wells be constructed in the following manner:

"First sink a 10-inch casing by means of a water jet, driving the material out of the bore of the pipe. Remove the jet pipe and replace with a 3- or 4-inch screen pipe having suitable perforations and centered by guides to the bottom of the casing; and fill the space between the screen pipe and casing with moderately fine sand. Then withdraw the outer casing, leaving in place only the perforated pipe, now surrounded with moderately fine sand, however. Finally insert a 1½- or 2-inch pipe in the perforated pipe, with its end near the bottom for the pump suction and draft through it. In this way it is believed that the ground water may be so lowered and kept down below the foundations as to prevent the forcing up of the bottom material as excavated, and as to make possible the successful dispatch of the work."

The method of construction adopted by T. W. Kinser & Sons, to whom the contract for the entire work had been awarded, was briefly stated, that of driving two lines of sheeting around the outside and inside of the storage well wall and excavating the material between them, leaving the core to be excavated after the completion of the wall. Six-inch grooved spruce sheeting, with 2-inch splines, was driven by means of a pile driver and water jet 30 feet in depth to Grade 75, in a ring 67 feet in internal diameter. About 7 feet inside of this was driven a line of 4-inch tongued and grooved sheeting, 22 feet long, on 11 chords of various lengths.

The excavation of the enclosed material was then begun September 1, 1898. On top was found a layer of about 2 feet in thickness of clayey loam or alluvium, followed by about 5 feet of sand or gravel; underneath this a blue silt of the finest quality, similar to the infusorial earth found in the meadow near by, extend-

ing to an unknown depth—more than 35 feet below the surface of the ground. This fine material, when dry, was excavated with great ease, being of the consistency of cheese, but when wet it maintained a uniform level in the excavation and was tough and rubbery. The material was readily excavated to a depth of from 15 to 17 feet, but thereafter the difficulty increased rapidly, and the effort was made to sink the excavation in small sections by transverse bulkheads approximately 20 feet apart. Progress was very slow, as new material was continually brought up from the bottom by the inflow of ground water, which was, however, small in amount, being handled from the greatest depth by one Edson hand pump. The material in the core and around the outside of the excavation gradually settled; the outside sheeting itself settled, and was driven in at the bottom until it occupied the position that the foundation wall itself should have; and transverse cracks appeared in the core and around the outside of the excavation. At that point, October 9, work upon the structure was suspended by Messrs. T. W. Kinser & Sons, and the excavation was allowed to fill with water and remain in this condition until November 1, when the entire contract was formally abandoned.

The probable cause of the failure of the method of construction adopted by the contractors is not difficult to trace. Material of this kind, when wet, is reasonably homogeneous and mobile, and transmits pressure in all directions in a similar manner to water. It requires but little water to make it run for a long time. Consequently the failure of the method is to be ascribed to the following facts—the failure to lower the ground water level to a point at or below the bottom of the structure; the driving of the outer line of sheeting to so great a depth below the foundation for the structure, without placing a hoop around the outside sheeting at its top, when the only opportunity to brace the sheeting was from the inside to the core as the material was excavated, which left a large unbalanced pressure from the outside at the bottom; the bracing of the outside sheeting to the inside core, itself subject to deformation; and the driving of the inner sheeting supporting the core to so small a depth that the lower end was nearly exposed, in making the excavation for the foundations of the wall. Thus the bottom of the outside sheeting was driven inward and the top outward by the unbalanced forces, while the sheeting itself settled locally and unequally as the work was excavated at various points around the ring.

No payment was made T. W. Kinser & Sons for this work, as the structure was in such a condition as to make the final execution

of the work more difficult and expensive than if nothing had been done upon it.

It seemed advisable thereafter to separate the storage well contract from the other work remaining to be done, and on January 6, 1899, a circular letter was sent out to seven firms of recognized standing, who had handled work of this character, inviting bids upon the construction of the storage well. Two alternative designs were proposed—one being the original design, and the other that for a well of equal capacity, but of greater diameter, to clear the original excavation. The condition of the work was clearly set forth in the call, and a description was given of the method pursued by the former contractors and the probable cause of its failure. The right was reserved to pass upon the method of construction to be adopted, the plan originally suggested to T. W. Kinser & Sons being suggested as satisfactory to the Commissioners, as well as the freezing and pneumatic processes, if not too expensive.

In response to this call six bids were received on January 26, 1899, as follows:

Proposals for constructing Storage Well and Screen Chamber for the Concord, Mass., Sewerage System, opened January 25, 1899.

BIDDERS.	AMOUNT OF BID. 60′ Well.	70′ Well.	METHOD OF CONSTRUCTION PROPOSED.
Engineering Contract Co., 15 Broad St., New York, successors to Sooysmith & Co.	$31,300	$34,700	Pneumatic Process.
Metropolitan Contracting Co. (C. L. Perrin & H. H. Carter), 95 Milk St., Boston	30,000	(Diameter not stated.)	Plenum-pneumatic Process, in a new location clearing old work.
Charles G. Craib, 17 Otis St., Boston	22,000	22,000	Six-inch spruce piling 30 ft. long, etc.
Guy C. Emerson and Edward A. Clark, 170 Summer St., Boston	18,935	18,974	Sheet piling similar to present work, or by wells, as suggested, driven inside of excavation.
Bell & Co., 24 Warren St., Roxbury	17,000	17,000	Freezing Process, or two or more concentric rows of sheet piling, working three eight-hour shifts.
Lucian A. Taylor, Tremont Bldg., Boston, and Worcester, Mass	14,800	16,150	Tubular filter wells for lowering ground water, as suggested by Sewer Commissioners.
B. F. Smith & Brother, Boston	....	....	Unable to bid, on account of other work.

T. W. Kinser & Sons, Boston, original price under contract for building the sewerage system, $7,950.

The contract was awarded to the lowest bidder, Mr. Lucian A. Taylor, of Worcester, and it is interesting to note, by way of comparison, that the original contract price of this work under the Kinser contract had been $7950, while the highest bid for it out of the sixteen bids received on the sewer work June 22, 1898, was $12,610.

Mr. Taylor adopted the method of construction first suggested by Mr. William Wheeler, member American Society of Civil Engineers, one of the Sewer Commissioners, and the writer, and on March 10, 1899, began driving the wells which were to be used in lowering the ground water. Fourteen wells were driven around the outside of the excavation to a depth of about 32 to 34 feet, and an open braced trench was dug around the outside of these through the gravel to the surface of the fine material, draining to two hand pumps located on opposite sides of the excavation. The wells were completed on March 29, a small pitcher pump being used on each driven well, and pumping was immediately begun and continued night and day thereafter.

It may be of interest to note that the sand, used as a jacket about the pump wells previously described, was a clean, sharp and moderately coarse sand. The analysis of it made by the writer showed it to be of an effective size (or 10 per cent. finer than), 0.25 mm., and to have a uniformity coefficient varying from 2.8 to 3.4.

On April 26 the excavation was begun, the core being excavated and the outside sheeting supported by a cellular and fan-shaped bracing. On May 9, finding that the fourteen wells did not keep the ground water level down satisfactorily, Mr. Taylor drove sixteen additional wells inside of the sheeting—half to a depth of 27 feet, the other half to a depth of 35 feet—and pumping was continued night and day from that time until about the first of July.

Space forbids a recital of the many difficulties encountered in the execution of the work. Suffice it to say that on June 10 the bottom was excavated to about Grade 84—within a foot or two of the proposed foundation for the structure. The outside sheeting, which had been left in such a deformed condition by the contractor the previous year, continued to settle so seriously and unequally as to make it impossible to keep the bracing of the structure in line. Indeed, it seems highly probable that, had new sheeting been driven in the beginning by Mr. Taylor and the old withdrawn, the work could have been executed much more rapidly and with far less difficulty and expense. On June 15 one of the 10x10-inch yellow pine through timbers in the bottom set of bracing gave way.

and two days later the corresponding timber in the second or middle set failed, and that of the third set bade fair to follow. It was a most critical period. The outside sheeting, which had come in so at the bottom as to make it impossible to build the well of the

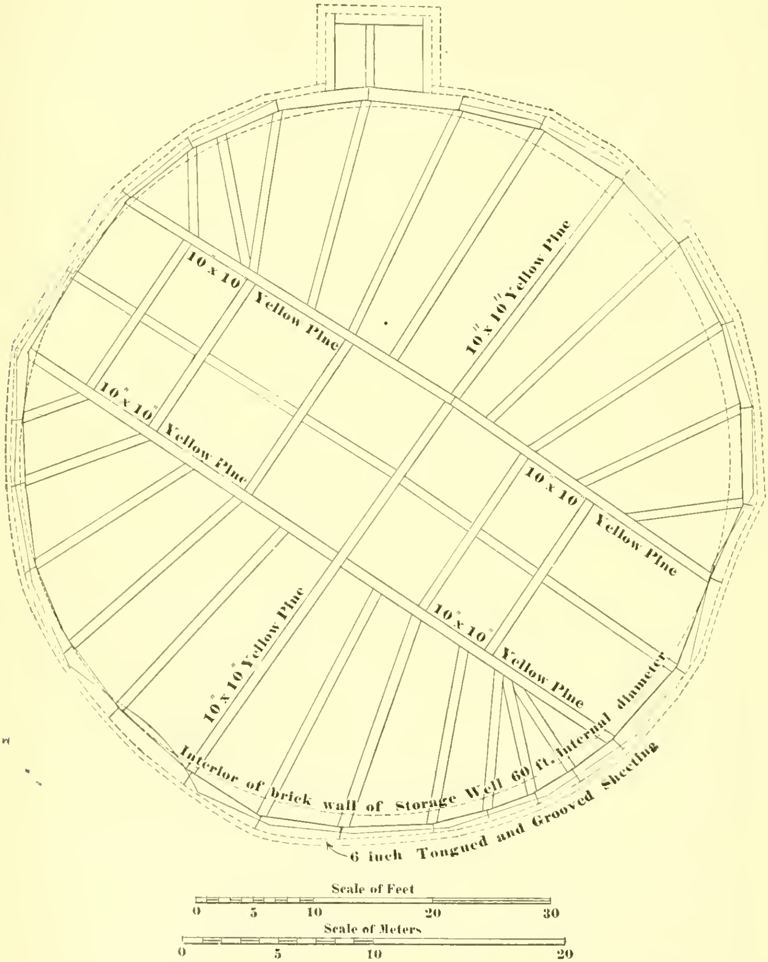


FIG. 2. BOTTOM SET OF STORAGE WELL BRACING. GRADE 85 +.

NOTE.—All braces are 8" x 8" Spruce unless shown otherwise. Rangers are made of 2" x 8" Spruce plank spiked together. Surveys of June 12 and 19, 1899.

diameter originally contemplated, without cutting the sheeting, continued to encroach more and more upon the core, and matters were in such a serious condition that it was feared the entire system of sheeting and bracing might gradually fail.

The failure of the storage well would have meant not only the entire loss of the structure to the contractor and the consequent possibility of financial embarrassment to him on the rest of the contract work, but a delay in the completion of the sewerage system of another six or even twelve months, as the construction and equipment of the power station and municipal light plant were dependent upon the previous construction of the storage well.

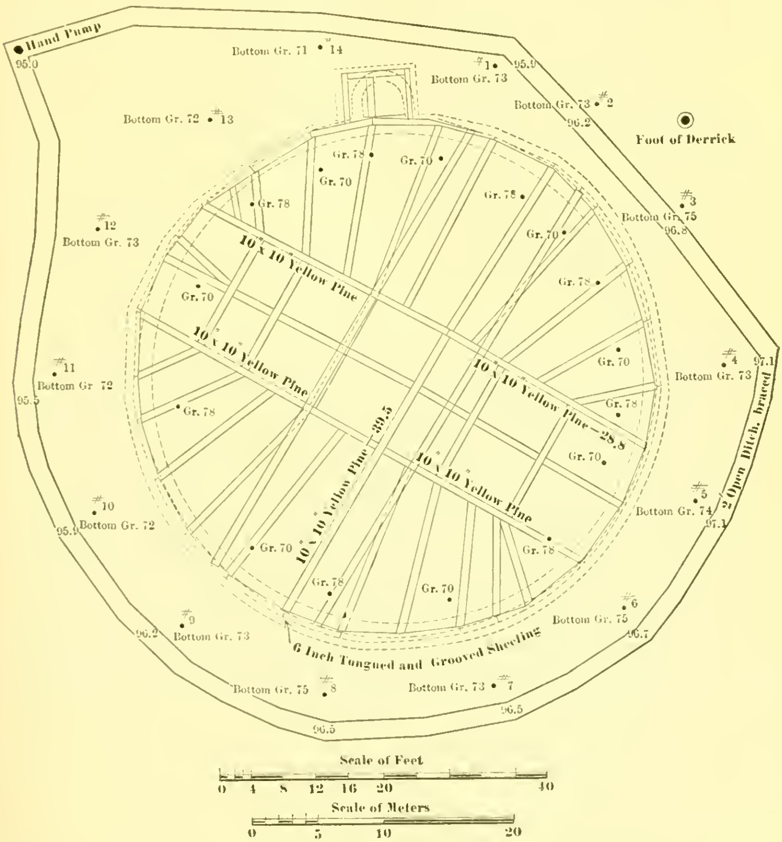


FIG. 3. TOP SET OF STORAGE WELL BRACING. TOP AT GRADE 96.

NOTE.—All braces are 8″ x 8″ Spruce unless shown otherwise. Rangers are made of 2″ x 8″ Spruce plank spiked together. Driven wells with grade of bottom shown thus • Gr. ... General level of surface of ground = Gr. 105.0.

At this point the contractor was advised to put in an additional and new system of bracing throughout the bottom, adequately designed to hold the sheeting against further encroachment into the well, and in the interest of the immediate completion of the work a reasonable reduction in the size of the storage well was authorized upon certain specified terms.

In order that every possible precaution should be taken to prevent the collapse of the structure at such an anxious time, the writer asked Mr. Howard A. Carson, Chief Engineer of the Boston Transit Commission, to come to Concord to examine the work. This Mr. Carson very kindly did at some personal sacrifice, and examined the work carefully. He expressed the opinion that in material of this character the failure, if it should occur, would not come about suddenly, but gradually, and suggested that if the storage well could be somewhat reduced in size it might be possible to save the work which had been done, by depositing concrete on the bottom of the excavation to stiffen the bracing, and by making certain additions to the bracing. Mr. Carson also kindly passed judgment upon the thickness of the walls of the chamber as designed, and pronounced them adequate and satisfactory. Steps were immediately taken to modify and strengthen the bracing, and concrete was deposited in the bottom of the excavation. This concrete materially increased the thickness of the bottom of the storage well, requiring about two hundred additional barrels of cement, furnished by the contractor, but was undoubtedly the salvation of the structure.

A layer of screened gravel was first placed upon the surface. Sectional platforms of 3-inch tongued and grooved spruce, covered with 2-inch tongued and grooved spruce laid at right angles and thoroughly spiked thereto, were cut in between the lower set of bracing timbers, resting upon the gravel. On these was deposited the first layer of concrete, pumping being continued until the concrete had thoroughly set, the water coursing underneath the platforms and along the lines of timber between the blocks of concrete. As the water pumped by the pulsometer pump carried about 9 per cent. of silt, some settlement of the platforms resulted, but not sufficient to cause serious trouble. The bracing timbers were thereafter cut out from between the blocks of concrete and replaced with concrete.

On this first layer of concrete, which was considered merely as a substitute for the continuous timber platform called for in the original design, was placed the concrete floor of the inverted parabolic groined arches. As the wall was built up upon this concrete base, the water was allowed to stand in the inside as well as on the outside of the structure, in order to equalize the pressure and do away with the necessity for further pumping, not only on account of the expense thereof, but also on account of the danger of future settlement resulting therefrom. It is interesting to note that in two cases where small horizontal cracks had opened in the brick

wall when first laid, they closed as the height of the wall and the load upon the structure increased.

Thereafter the work upon the masonry progressed slowly but satisfactorily, the concrete floor invert being finished July 12, the brick walls August 16 and the roof concrete September 19.

Mr. Taylor gave his personal supervision to this work from time to time, particularly during the dangerous period in the early part of June, and he deserves great credit for the manner in which the work was executed.

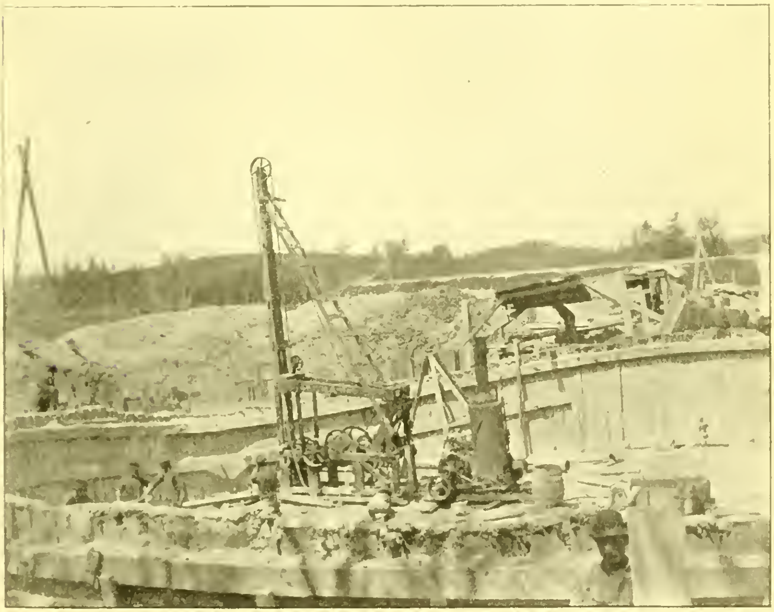


Fig. 4. Well Driving, May 9. 1899.

A record was kept of the amount of water pumped from the wells and the trench around the outside of the storage well during the latter part of April, May and the early part of June. The results, however, are only approximate, as the measurement of the water pumped from the wells was made by counting the number of buckets of water pumped during the day and night, while that from the trench was measured by taking readings from time to time with small V-shaped and rectangular weirs. They are interesting, however, as giving an idea of the amount of water which even so fine a material as that can pass.

U. S. GALLONS OF WATER PUMPED PER 24 HOURS FROM

Date, 1899.	Central Excavation.	External Drain.	Driven Wells, Day.	Outside Sheeting, Night.	Total U. S. Gallons, Approx.	Height of River.*	Inches of Rain.	REMARKS.
								*Low water = Gr. 100.0.
April 21	23,300	33,700	951	639	58,600	104.7		Pumping from 9 wells only.
" 22	23,300	33,700	959	1,778	59,800	104.5		{ " " 9 " in a. m. / " " 14 " in p. m.
" 23	23,300	33,700	2,041	2,059	61,100	104.4		" " 14 "
" 24	23,300	33,700	2,329	2,324	61,600	104.1		" " " "
" 25	17,400	44,100	2,422	2,510	66,400	103.9	0.13	" " " "
" 26	11,100	39,200	2,441	2,507	55,300	103.7		" " " "
" 27	9,800	31,900	3,040	2,843	47,600	103.6		" " " "
" 28	6,600	32,000	3,479	3,445	45,500	103.5		" " " "
" 29	6,200	30,700	3,259	3,079	43,200	103.3		" " " "
" 30	6,200	27,000	3,143	3,032	39,400	103.2		" " " "
May 1	6,200	25,900	3,273	3,034	38,400	103.1	0.02	" " " "
" 2	6,200	25,900	3,318	3,376	38,800	102.9	0.29	" " " "
" 3	6,200	25,300	3,122	3,302	37,900	102.8	T	" " " "
" 4	8,200	25,300	3,228	3,183	39,900	102.6		" " " "
" 5	8,200	25,300	3,387	3,159	40,100	102.5		" " " "
" 6	8,200	24,900	Stopped pumping for a few days.	Stopped pumping for a few days.	33,100	102.4		
" 7	8,500	24,900			33,400	102.3		
" 8	8,500	24,900			33,400	102.2		

Hereafter the 16 driven wells in the main excavation were made to discharge into a trough leading to a tub from which the water was pumped to the surface by an Edson pump. The 14 driven wells around the outside of the sheeting discharged into the external drain or trench.

May 19	12,600	25,800			38,400	101.1	0.04	
" 20	14,400	20,200			34,600	101.0	0.04	
" 22	14,400	25,900			40,300	100.9	*	*May 21, 0.14″ rainfall.
" 23	15,700	23,400			39,100	100.8		
" 24	14,400	23,400			37,800	100.8		
" 26	13,500	23,400			36,900	100.7		May 28, 0.10″ rainfall.
June 1	14,400	18,600			33,000	100.6		" 29, 0.04″ "
" 2	14,400	20,200			34,600	100.6		
" 9					30,600	100.5		June 7, 0.17″ rainfall. / " 8, 0.31″ "

Surface of Ground, Gr. 105.0
Low Water in Sudbury River, Gr. 100.0
Bottom of Excavation, Gr. 83.0 Approx.

Total Rainfall,	January,	3.02″
" "	February,	3.47″
" "	March,	3.98″
" "	April,	1.50″
" "	May,	0.97″
" "	June,	4.11″
" "	July,	3.36″
" "	August,	3.07″
" "	September,	4.01″
" "	October,	1.63″
" "	November,	2.49″
" "	December,	1.72″
	Total 1899,	33.33″

While grave difficulties were encountered in the construction of this work, in spite of the method of building adopted, it is believed that they were primarily due to the condition of the sheeting at the inception of the work in the year 1899. This irregularity of the sheeting prevented the proper bracing of the structure and resulted in its deformation, due to unequal settlement, to such an extent as nearly to bring about the total collapse of the work. It is true that the ground water was never lowered quite to the bottom of the excavation, but this was probably due more to the

form of pumps used and the spacing of the driven wells than to any inherent defect in the method pursued. However, the ground water was lowered within a distance of a few feet at most above the bottom of the excavation, and both the contractor and the writer feel certain that without the use of the driven wells the execution of the work would have been physically impossible, except by some such method as the pneumatic or freezing processes.

The storage well as finally built has an internal diameter of 57 feet, with a storage capacity in the well itself up to Grade 97,

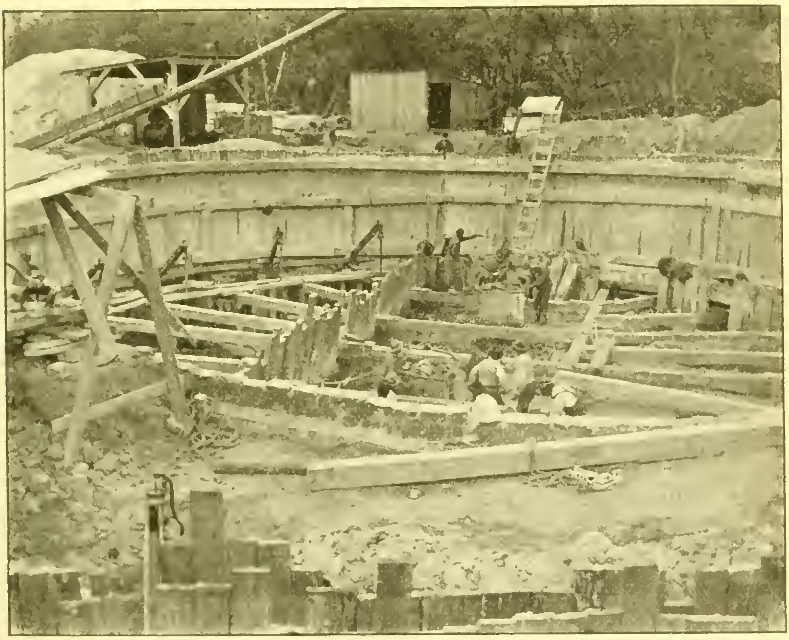


Fig. 5. Storage Well, May 20, 1899.

the assumed high-water level to which the sewage is backed up into the trunk line for a distance of about 3000 feet across the meadows, of 222,000 gallons; brick walls 24 inches in thickness reduced to 20 inches in the last 10 feet, vertically; an inverted parabolic groined arch bottom of concrete of 12 feet 9 inches span, 1 foot rise, and varying, as previously described, from 2 to 3 feet in thickness (nominally 1 foot at the invert crown); and an elliptical groined arch roof of concrete of 12 feet 9 inches span and 3 feet rise, supported on 24-inch brick piers 14 feet 9 inches on centers. The roof concrete is 6 inches in thickness at the crown, the space over the piers being filled in and giving a horizontal plane surface to the top of the masonry.

The total combined capacity of the storage well, screen chamber and trunk sewers is as follows:

	GALLONS.
Up to Grade 92.5, the invert of the 12-inch trunk sewer	138,000
To Grade 97, the contemplated ordinary high sewage level	242,000
To Grade 100, mean low water in the Sudbury River	319,000

The concrete in the floor and the roof was made of Atlas Portland cement and screened gravel, mixed in the proportions of 1 part of cement to 2 parts of sand to 5 parts of gravel. The brick walls were built of hard burned sewer brick, laid in Atlas Portland cement mortar, mixed 1 part of cement to 2 parts of sand; plastered outside with a $\frac{1}{4}$-inch layer of Portland cement mortar mixed 1:1 and thoroughly troweled; and inside with a grout of the same laid on with a plasterer's brush.

The contract cost of the storage well to the town, exclusive of cement, was $14,800; the total cost, including ironwork, cement, etc., but exclusive of engineering, being $16,955.46. The estimated cost to the contractor of the storage well floor was $0.74 per square foot; of the brick walls $11.17 per cubic yard, including the cost of cement; and of the roof, $0.38½ per square foot. The average thickness of the roof concrete, as figured from formulæ deduced by the writer (see "The Groined Arch as a Covering for Reservoirs and Sand Filters; Its Strength and Volume," Proceedings of the American Society of Civil Engineers for May, 1899), was 0.92 foot.

Mr. Taylor estimated his loss upon the storage well contract as something over $2000, making the total cost to him $16,800, due primarily to the length of time required for building the structure and the resulting high cost of pumping, which had to be done by hand and which was continued night and day from about April 1 to July 1, 1899.

The work is therefore the more creditable to Mr. Taylor, as, in spite of the great difficulties of construction, cost and time required, the structure stands to-day complete, secure and well built.

DISCUSSION.

Mr. Lucian A. Taylor.—Mr. Metcalf, in his very interesting account, has pretty fully covered the essential features of the construction of the storage well at Concord. There are, however, some points to which I desire to call attention.

First of all, I will say I had great faith in the efficiency of the driven wells surrounded by filtering material to lower the ground

water. It was at first suggested to drive ten of these wells. However, I did drive fourteen. After using these wells for a while I discovered they were not lowering the ground water, although we were pumping perfectly clear water and more in quantity than I had supposed we should be able to. However, the supply still continued, and I drove sixteen additional wells, as stated by Mr. Metcalf. From these also the filtration was perfect, and we pumped perfectly clear water from them until the excavation was at such a depth that the strainers were exposed in some cases. When the

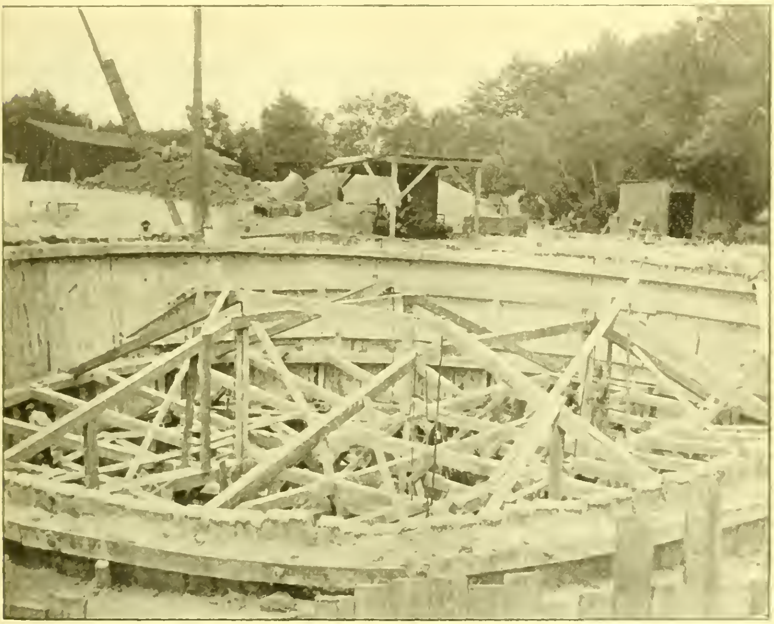


FIG. 6. STORAGE WELL BRACING, JUNE 10, 1899.

wells outside the excavation were no longer needed, the pipes were drawn from the ground. This was found to be very difficult work, and most of the strainers were left in the ground. The difficulty was owing to the movement of the ground toward the excavation, even at the depth of 32 or 33 feet below the original surface. The ends of the strainers were carried toward the center of the excavation. Some that were withdrawn curved from 25° to 45°, and, from indications of the broken ones, the deflection must have been nearly 90°. In other words, the end suction pipe must have been very nearly horizontal. Repeatedly, strains of 10 tons were required to pull the pipes.

It was the intention to have 3-inch strainers on all the wells, but only a few of these could be procured, and about one-half the

first set of wells had $2\frac{1}{2}$-inch strainers. Most of the strainers for the sixteen wells last driven had 2-inch strainers. In all cases they were in two pieces, or 3 to $3\frac{1}{2}$ feet in length.

The pipes attached to the pumps were nearly all $1\frac{1}{4}$ inches in diameter. Some, however, were only 1 inch in diameter. So far as could be observed, there was no material difference in the quantity of water obtained from the different wells, although the 3-inch strainers undoubtedly did give an additional quantity.

As an illustration of the difficulty of lowering the ground water, I will state that in excavating the inner core, after the water in the trench had been lowered for a month, it was found that the quicksand one foot below its surface was very wet and shaky, although 10 feet above the level of the bottom of the trench. The inner sheet piling, although quite irregular, was, nevertheless, practically tight and retained the water in the inner core. A test pipe, driven in the center, showed the water level with the top of the quicksand.

In the timbering of the structure the braces were strengthened very materially by spiking planks on two or three sides of the timbers, thus making many of the 10 x 10-inch timbers 13 x 14 or 16 inches, and the 8-inch timbers 8 x 12 and 10 x 12 inches. Great difficulty was experienced in fitting the rangers, which were from 7 to $7\frac{1}{2}$ feet in length, to the outside sheeting, owing to its great irregularity, especially with the lower set of timbers. Some of the sheeting was broken off, and in some cases one plank was entirely behind or in front of the others. After the braces and rangers were in place, blocks were driven between the back side of the rangers and the sheeting. Often there was between the rangers and the sheeting a space of 7 and 8 inches which had to be filled in this way.

It was quite difficult to place the heavy timbers in position in the second and third sets of bracing, as there was no way to get long timbers between the bracing of the upper set. The main rangers were cut in three pieces, and afterward the joints were heavily reinforced. In spite of all precautions, at two or three different points the outside sheeting encroached considerably. At two points an excavation was made on the outside of the sheeting, and the 6-inch sheeting then cut away to make room for the brick wall. It would undoubtedly have been better if the surface drain had been placed much farther away from the excavation, say 30 feet or more. As it was, after a time the trench became involved in the general settlement, and at last had to be abandoned, as it was inoperative, the bottom of the trench having settled so much as to make it useless. Before this occurred it was a source of constant trouble to

keep the trench in proper condition to carry the water from the pumps and the surface soil to the pump well. Every day, and sometimes twice a day, the bracing had to be remodeled to a greater or less extent. The entire settlement of the sheeting was about 6 feet, and this involved also a distance of about 20 feet outside the line of the sheet piling. The lower set of bracing, which I had designed to be about 4 feet above the bottom of the excavation, was in greater part carried below the bottom of the foundation, owing partly to its failure in the center and also to the settlement of the entire structure. All efforts to bring the lower set of timbering to

FIG. 7. CHARACTER OF MATERIAL WHEN THOROUGHLY DRAINED.

proper place were useless, and it was largely reconstructed with new timbers, quite a quantity of 16 x 16-inch hard pine timbers being used. Almost the entire lower set of bracing, with some jack-screws, are now buried below the bottom of the well. The failure of the lower set of bracing also involved, to a certain extent, the second or middle set, but not to so serious an extent. Fortunately, the four trusses to sustain the upper set of bracing, held, although they required constant attention. Often during the twenty-four hours there was a difference in level of the different parts of the structure of 12 to 18 inches, and at one time one portion of the sheeting went down 2 feet or more in twenty-four hours.

This variation and deflection of the outside timbering of course brought great stresses upon the rangers of the entire interior bracing. None of the 8 x 8-inch spruce braces failed, as they were independent each of the other, and only took direct thrust which they withstood. The 6-inch piling was in very much worse condition than was supposed, especially near the bottom of the excavation.

It is quite probable that, with an entire new set of sheeting properly driven, the well would have been constructed at less expense, notwithstanding the extra cost of the sheeting. The time

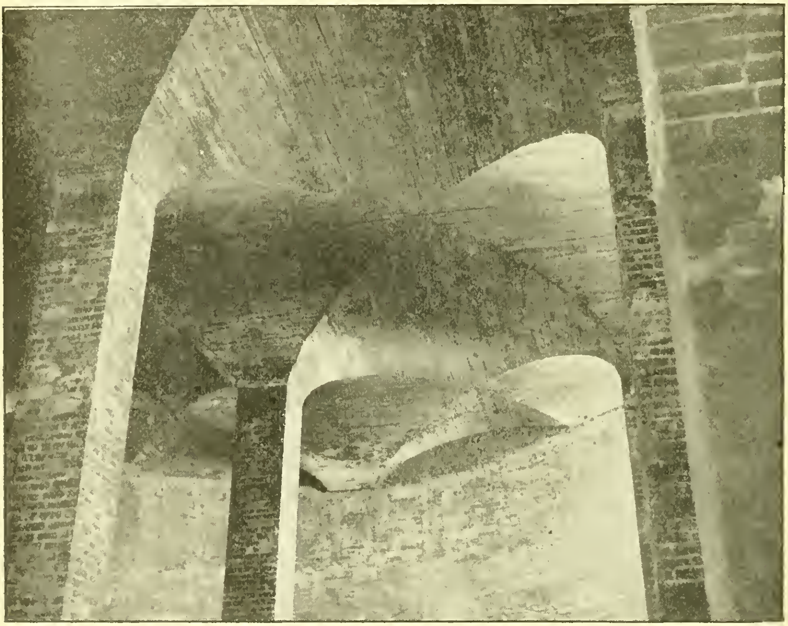


FIG. 8. VIEW OF GROINED CONCRETE ROOF, SEPTEMBER 23, 1899.

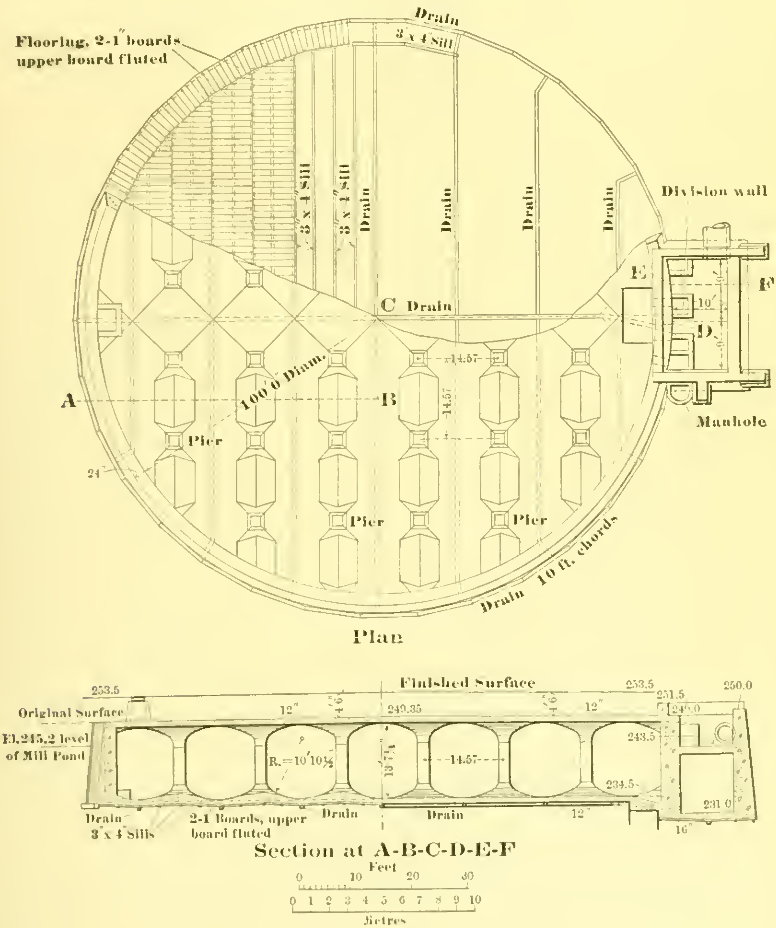
required to put the bracing in place, and also to keep it in condition, increased the cost of pumping to a very great extent. The mere excavation of material was comparatively a small part of the expense.

MR. THOMAS F. RICHARDSON (by letter).—In September, 1898, the Metropolitan Water Board began the construction of a storage reservoir for sewage, this reservoir being part of the works for diverting the sewage of the town of Clinton, Mass., from the Nashua River. The reservoir is in the northern part of Clinton, and is located on the bottom land, about 120 feet from the south bank of the Nashua River.

The conditions encountered appear to be almost identical with those found at Concord, and described by Mr. Metcalf in his inter-

esting paper,—namely, a plentiful supply of water and very fine material.

The Clinton reservoir is circular, and similar in design to the one built for the town of Concord, but considerably larger, the diameter being 100 feet, with a capacity of 669,100 gallons below the overflow, which is about 1.5 feet above mean low water in the river.



The bottom consists of inverted segmental groined arches of concrete, which rest on a light platform built of two thicknesses of 1-inch boards fastened to 3 x 4-inch sills. The lower board is plain, and rests on about 3 inches of coarse sharp sand; but the upper board is fluted on its lower side, having small semicircular

channels $1\frac{1}{2}$ inches apart and 1 inch in diameter. These channels connect with wooden box drains, which run at right angles to the boards and parallel with the sills, and are placed at frequent intervals under the bottom of the reservoir. This style of platform provides very efficient drainage for the concrete, and the cost is small.

The elliptical groined arch roof of concrete is supported by brick piers 2 feet in section and 14.57 feet apart.

On the north side of the reservoir are double pump wells, each about 9 x 10 feet, the circular wall of the reservoir forming one side of the pump wells, the bottoms of which are 3 feet 6 inches below the bottom of the reservoir.

Following are various elevations:

Mean low water in Nashua River	245.2
High water, February 13, 1900	251.7
Surface of ground at reservoir	249.0
Top of fine sand at reservoir	239.0
Bottom of reservoir masonry	233.5
Bottom of pump well masonry	229.7
Top of refilling over reservoir	253.8

The material encountered was similar to that found at Concord. At the surface was about 3 feet of soil and subsoil, followed by about 7 feet of clean gravel or sharp sand. Underneath this, for at least 40 feet, was a fine blue silt, much of which had no appreciable grain and appeared like wet clay to the touch.

The specifications, which were a part of the contract, provided that the contractor should adopt the following methods for doing the work:

"METHODS OF EXCAVATING FOR THE RESERVOIR AND PUMP WELLS.

"The borings indicate that the bottom of the gravel and the top of the fine sand at the site of the reservoir and pump wells are approximately at elevation 239. The contractor shall, if feasible, excavate all material above elevation 241, with slopes of one horizontal to one vertical; said slopes to start from the outside of the bottom of the masonry. After the material, or so much of it as the engineer may direct, has been excavated to these limits, the contractor shall excavate for the pump wells, protecting the excavation with close sheeting and bracing. After the masonry of the pump wells has been raised 2 feet above the bottom of the inside of the wells, he shall proceed to excavate a trench of such width as the engineer shall direct, for building the outside wall of the reservoir, starting at the pump well and thoroughly supporting the material at the sides by close sheeting and bracing. The excavation of the earth inside of the wall of the reservoir shall not be continued until

the wall has been built to a height of at least 5 feet. Care must be taken to have all sheeting tight, and driven far enough below the bottom of the excavation to prevent the admission of sand. The method of construction above indicated can be changed only with the written permission of the engineer."

The contractors, Owen Cunningham & Son, followed out the requirements of the contract and excavated the material to elevation 241, or about 2 feet above the fine sand, the work being done with carts. The close sheeting for the pump wells was then started. The outside dimensions of the pump well masonry were about 18 x 27 feet, and the sheeting was laid out for an excavation 20 x 31 feet, a 4 x 4-foot sump, which was also sheeted, being excavated at one end. Two-inch spruce plank without tongues or splines was used for sheeting, and was very thoroughly braced by 8 x 8-inch timbers, additional bracing being placed as the excavation progressed, so that the bracing was very close to the bottom of the excavation. The sheeting was driven by hand with wooden beetles, and was kept 3 or 4 feet below the bottom of the excavation. When the excavation had very nearly reached the bottom a second row of sheeting was driven inside of the other sheeting. After the excavation was finished, a light board platform, the same as used in the reservoir, was placed, and the concrete of the pump wells built to 2 feet above the bottom of the wells, and the contractors' pump was moved so as to use the partially constructed pump wells as a sump. A start was then made at both sides of the pump wells on the trench, about 7 feet wide, for the outside wall of the reservoir. Two-inch plank was again used for sheeting, and the material in the trench was excavated to grade in sections about 20 to 30 feet long; and as soon as the excavation of a section was finished the light board platform was put in place and braced to the sheeting. At the outer end of the boards of this platform, the boards being laid in radial lines, and outside of the masonry, a 4 x 8-inch wooden box drain was provided which connected with the fluted boards, intercepting and conducting the water to the pump wells.

The contractor began to build the concrete ring wall of the reservoir when about one-half of the platform had been put in place, starting close to the pump wells. As soon as the ring wall was completed to elevation 239 or 240 the trench on the outside was refilled to the top of the wall and the sheeting removed, when the excavation of the material on the inside was commenced. This material was comparatively dry, and was handled without difficulty.

When the location of the reservoir was selected it was evident that there would be considerable water to handle in building it, and

the wash drill borings showed the underlying material to be very fine and without doubt difficult to handle unless properly drained. The system of drainage adopted proved very efficient, and none of the excavation was difficult except that for the pump wells, where some trouble was encountered in properly draining the considerable area inclosed within the sheeting during the progress of the excavation.

The work done with carts above elevation 241 having been excavated to slopes of 1 to 1, starting from the outside of the bottom of the masonry, there was a berm outside of the sheeting about 10 feet wide at the pump wells and about 6 feet around the reservoir. This method of doing the work caused the handling of considerable extra material, both in excavation and refill, but it was material cheaply handled and the load on the sheeting was considerably lessened, making it possible to use light plank driven by hand.

No masonry was at any time laid in water, and the fine material under the reservoir was hard and could be readily walked upon, showing it to be thoroughly drained.

No record was kept of the amount of water pumped, but before the ring wall was built and the back filling made a 6-inch centrifugal pump was worked nearly to its capacity night and day. After the ring wall was completed and the back filling made a 4-inch centrifugal pump handled the water, working to about half of its capacity. The water pumped was practically free from silt, except during the excavating of the pump wells.

The excavating of the material at the reservoir cost the contractors about 55 cents per cubic yard, which includes the cost of lumber, pumping, etc. The whole cost of the reservoir, not including iron work or engineering, was $14,987. This includes the cost of cement and all other materials except iron work.

EXPERIENCES IN THE OPERATION AND REPAIR OF THE HYDRAULIC DREDGES ON THE MISSISSIPPI RIVER.

By F. B. Maltby, Member Engineers' Club of St. Louis.

[Read before the Club March 7, 1900.*]

The subject of the hydraulic dredges built for the Mississippi River Commission has received pretty thorough discussion since the inception of the project by Col. Henry Flad some eight or nine years ago. The writer does not purpose giving a historical discussion of various schemes for dredging the river, or a description of the dredges themselves, as that part of the subject has been thoroughly exhausted in the paper presented before the American Society of Civil Engineers by J. A. Ockerson.†

The writer has thought that the relation of some experiences in the operation, the methods, the results obtained and the repairs made necessary through wear in operation might prove of interest, and possibly of some value to those interested in the subject.

During the temporary absence, from July, 1898, to May, 1899, of Mr. C. W. Sturtevant, who was commissioned as captain in the Third Regiment of Volunteer Engineers, the writer was in charge of dredging operations under the Mississippi River Commission as "superintendent of dredging."

During the season of 1898 the dredging plant consisted of six dredges, the "Alpha," the "Beta," the "Gamma," the "Delta," the "Epsilon" and the "Zeta." The "Beta" was, however, undergoing extensive alterations, and was not in commission during the season.

Each dredge while in commission was accompanied by a towboat, a pile driver, a plunder barge and a coal barge. In addition, there were connected with dredging operations three survey parties, each quartered on a steamboat, and an inspection boat. The entire fleet in operation during the season consisted of five dredges, nine steamboats, five pile drivers and the necessary barges and fuel boats.

ORGANIZATION.

The organization was as follows: The dredging operations are carried on under the direction of the Secretary of the Mississippi River Commission, who is also the disbursing officer and has an office in St. Louis.

The fleet was in direct charge of a superintendent of dredging, who determined on the localities to be dredged and the disposi-

*Manuscript received May 24, 1900.—Secretary, Ass'n of Eng. Socs.

†Trans. Am. Soc. C. E., Vol. XL, December, 1898.

tion of the various dredges, ordinarily located the cuts to be made at each point and in general had the responsible charge and supervision of the operation of the fleet. The routine office and clerical work, which in itself is no small matter in connection with operations of this magnitude, passed through his hands. A suitable boat was furnished for his use, and he was constantly passing over the river, sounding all crossings, keeping himself fully informed as to the condition of the channel and directing the operation of the dredges.

SURVEYS.

The river below Cairo (and the operations of the dredges under discussion are confined to that portion of the river) is divided into three districts. The first two have a length of about 100 miles, and the third extends, from the lower limits of the second, down stream as far as dredging was necessary. In 1898 this limit was Wilson's Point, La., 531 miles below Cairo.

To each of these districts was assigned a survey party, whose duty it was, at the beginning of the season, to make surveys of all crossings likely to become troublesome. These surveys are repeated at those points where trouble develops. On the maps of the results of these surveys was laid out the location of the channel proposed to be dredged. Surveys are made during dredging operations, and at various times after the work is completed.

The surveys are accurately made, but with experienced men they are made very rapidly. They are of the utmost importance, as without them no intelligent knowledge of conditions governing the location of cuts or of results obtained, except in a most general way, could be had.

It frequently happened that at points where shoal crossings had been reported by pilots these surveys showed the existence of better channels than those in use by steamboats, and that dredging was unnecessary.

Each party consisted of the engineer in charge, two recorders and the necessary boat crew.

Each dredge was in charge of a master, and carried a mate, carpenter, machinist, blacksmith, recorder, clerk and steward, two engineers and a double crew. The total number, amounting to about fifty men, were quartered and subsisted on the dredge itself. The duties of all are indicated sufficiently by their names, except possibly the recorder. He was usually a young man of some engineering education or training, and upon him devolved the duty of keeping the records of operation and the making of reports. He located, by means of sextant angles, the position of the dredge at

the beginning and end of each cut, and they were plotted on the maps furnished by the survey parties. The dredges were operated twenty-four hours per day, the division of time to each crew being the same as that usual on river steamboats. Records are kept of soundings taken at every 25 feet advance, ahead of the dredge, on each side and at the stern. Daily reports are made showing the number, length and average depth of cuts made, average rate of advance per hour, average steam pressure and average speed of pumps; also a distribution of time into placing plant, dredging, changing cuts, repairs, making up tow and towing and "waiting orders" if not in actual operation dredging. The towboats accompanying each dredge carry only a single crew. In 1898 five steamboats, of a size large enough to handle a dredge, were chartered at a cost of from $40 to $60 per day for boat and equipment only, not including crew, fuel or supplies. During 1899 the Government completed five steel-hulled towboats built for this purpose. They are 171 feet 6 inches long, 36 feet beam, and four of them have cylinders 22 inches diameter by 8 feet stroke; the other one 24-inch by 8-foot stroke.

Coal, which is one of the large items to be provided, was purchased in 1898 under a contract which provided that the contractor should deliver it in barge lots in his own barges, and at the dredges wherever they might be between Cairo and Helena. This arrangement proved to be a satisfactory one in practice, and no trouble was experienced in keeping a supply on hand.

A barge holds from 12,000 to 15,000 bushels, and is held alongside the dredge and the coal used out of it as needed, practically no coal being stored on the dredge.

Other supplies were purchased wherever they could be had to the best advantage, and were delivered on board the dredges by steamboats plying on the river and landing against them without hesitancy.

OPERATION.

After having determined on the location of a proposed channel, and having brought the dredge and plant to the vicinity, the head mooring piles are set at the upper edge of the bar if it is not over 1000 to 1200 feet across, the length of the hauling cables, and about 1000 feet from the lower edge if it is wider than this. These mooring piles are simply iron tubes about 11 inches outside diameter, with metal $\frac{1}{2}$ inch to $\frac{5}{8}$ inch in thickness. They are 35 feet long, and are made in two sections with a flange connection. A shackle is fastened to them at such distance from their lower end as it is desired that the piles penetrate the bottom, usually 15 feet.

The upper end is closed, and provided with a ring for handling. Near the upper end it has a hole drilled and tapped for 2½-inch pipe, and is connected by a length of ordinary fire hose with a pressure pump. The pile drivers, or, more properly, pile sinkers, are provided with the ordinary leads, but no hammer, a hoisting engine, pressure pump and necessary boiler. The piles are rapidly sunk by forcing water through their interior, escaping at the lower edge, and by their own weight. In sand it is very quickly done, as I have seen a pile sunk 15 feet into sand in two and one-half minutes from the time it was swung into the leads. The water pressure carried on the pumps is from 40 to 70 pounds per square inch. Before sinking a bridle line, simply a piece of cable 30 feet long, with an eye in each end, is fastened to the shackle and the free end kept above water. In the meantime the discharge pipe line has been connected up. The latter is in 50-foot sections, the sections being connected with rubber sleeves about 3½ feet long. The operation of slipping the sleeves over the ends of the discharge pipe is a tedious and disagreeable proceeding, owing to the fact that the discharge pipes are submerged for about one-third to one-half of their diameter. Those who have struggled with forcing a pipe of slightly larger diameter into a piece of ordinary hose can possibly imagine the ease with which a 32 or 34-inch hose is forced over the end of a pipe half-submerged in ice cold water.

The piles being in position, the dredge is brought up as near them as possible and anchored by means of the spud. The hauling lines are then attached to the bridles. In attaching the cables to the piles it is found that the dredge is more easily manipulated if the cables cross,—*i.e.*, the cable from the starboard hauling engine is led to the port pile, and *vice versa*. The spud is then raised, the dredge dropped back with the current to the lower edge of the bar, the suction-head lowered and the main and jet pump started. The suction-head is ordinarily allowed to sink to the full depth, 15 to 17 feet, before pulling ahead; the dredge is then pulled ahead by the cables, the rate of advance depending on the material encountered and the depth of the cut. This rate varies from 60 to 150 feet per hour, and is sometimes higher. When the dredge has again reached the piles it is dropped back; a second cut is made alongside the first one, and the operation is repeated till the desired width has been obtained.

When the axis of the dredged channel is at an angle with the current, or when a strong wind is blowing, side piles may be set, to which lines are attached for holding the dredge in position. This sounds very simple, and the operation is a simple matter under

favorable conditions and in clean material. In 1898 the "Delta" was stationed at Island 34, and the material encountered was sand, gravel, lignite, shale, stumps, logs and the wreck of a coal barge containing coal. A channel was opened successfully through this material, but only after a long series of exasperating breakdowns; while, on the other hand, at Mrs. Hickman's crossing, where there was clean material, this dredge opened a channel 9 feet deep, 250 feet wide, in one day.

The "Gamma," in dredging a channel at Island 40, removed fifty-four logs, varying from 8 to 50 inches in diameter at the butt and having an aggregate length of over 1500 feet.

In consequence of this severe usage, accidents of a more or less serious character are not unusual. Each dredge is supplied with a machine shop, equipped with an engine lathe of 18 to 24-inch swing, a drill press, a shaper, a bolt and pipe machine and an emery wheel, all driven by a small independent engine; also a forge, with the necessary tools and a full assortment of small tools, hoists, etc.

At the beginning of the low-water season the troublesome bars develop rapidly, and in order to keep open a channel of the requisite depth it is necessary that the dredges be operated continuously at their full capacity; and they are not permitted to stop on account of any trifling disarrangement to machinery. At one time the piston in the low-pressure cylinder of the jet pump engine on the "Gamma" was broken, and at about the same time the air pump, operated in connection with the condenser to the main pump engine, was disabled. Dredging, however, was continued without a jet and without a condenser, a small amount of live steam being admitted to the low-pressure cylinder to equalize the work on the engine.

The rate of advance of the dredge did not seem to be materially affected. The material being handled was, however, a clean loose sand, readily moved, and the relation of this incident is not to be understood as indicating a belief that either the jet or the condenser may be dispensed with.

TESTS.

While the dredges were yet in the field it was thought desirable to determine their capacity under working conditions as nearly as these could be had. Each of the dredges, before acceptance from the builders, had been tested by measuring the discharge deflected for a brief interval of time, usually less than a minute, into a measuring barge. It was feared that test conditions might not be the same as working conditions, and that the determination of the short time interval required in filling the barge might be a source of error.

In making these field tests a location was sought where clean sand, of nearly the size of channel sand, could be found, and where there was no current, so that no material would be moved except by the dredge. The site was carefully cross-sectioned, and, after the test was completed, it was again cross-sectioned and the total amount moved was thus determined.

The "Gamma" was tested at Cow Island bar. Eight cuts were made, aggregating 4566 feet, and occupied forty-five hours and thirty minutes' time actual dredging. The material encountered was chiefly a rather fine sand, with a very small quantity of blue mud. The total amount of material moved was 45,856 cubic yards, or 1008 yards per hour. The average depth of cut was 7.16 feet, and the average advance per hour was 100.3 feet per hour. Average steam pressure, 145.6 pounds; average speed of main pump, 150 revolutions per minute. The vacuum on suction pipe of the main pump was 8.6 feet of water, and the discharge head 11 feet, or, in other words, the pump was operating against 19.6 feet of water. Seven hundred and fifty feet of discharge pipe was used. The original test shows an average capacity of 1523 yards per hour.

The "Delta" was tested at Island No. 18. The material was all sand, possibly averaging a little finer than channel sand. Four cuts were made, aggregating 2711 feet in length, and occupying twenty-seven hours and twenty-three minutes' actual dredging. Thirty-four thousand four hundred and sixty-two yards were moved, or 1259 yards per hour. During the last cut made the dredge was pushed to its highest capacity possible without sinking the discharge pipe. Distributing to this cut that proportion of the total volume moved to which it is entitled from a consideration of the rate of advance and depth of cut, we have 2550 yards per hour for the capacity limit of this dredge.

In the material encountered during the test, the capacity of the dredge, however, seemed to be limited only by the ability of the pontoons to carry the discharge pipes when loaded with the sand handled by the pumps. The average advance per hour was 99 feet, average depth of cut 6.55 feet, average steam pressure 151.1 pounds and average speed of pump 140.9 revolutions per minute. The suction-head was 16.3 feet, and the discharge 34.5 feet of water, or a total of 50.5 feet of water against which the pump operated. The original test gives a capacity of 1829 yards per hour with a 67.6-foot head. One thousand feet of discharge pipe was used in each case.

The "Epsilon" was tested at Phillips's bar in medium sand, with a small amount of mud. Four cuts were made, aggregating 2015 feet, and occupying twenty-four hours and fifty minutes;

during which time 32,407 yards were moved at the rate of 1305 yards per hour. The average advance per hour was 81 feet against a cut of 9.6 feet. Average steam pressure, 130 pounds; average speed of pumps, 178 revolutions. The combined suction and delivery head was 44.4 feet of water. One thousand feet of discharge pipe was used. The original capacity tests give an average of 2553 yards per hour with a total head of 58.5 feet.

In comparing these tests with the original tests allowance for loss of efficiency, due to wear in the pumps, must be made, and in the case of the "Gamma" this loss was evidently a large one, as will be shown later on.

A test was also made with the "Zeta" at Cherokee bar, to determine the feasibility of cutting a channel through a dry bar, and also to determine the capacity. So far as demonstrating the first-mentioned proposition, the test was an entire success. Into a dry bar a hole was cut approximately 500 feet long, 140 feet wide on top and having a depth of from $3\frac{1}{2}$ to 4 feet above water and 13 feet below water along the axis of the cut. The sides of the cut below water stood at a very considerable angle with the vertical. It would have been entirely practicable to have cut a channel entirely across the bar to deep water on the opposite side, a distance of 1200 feet, had it been desirable to do so.

The capacity test was, however, unsatisfactory, owing to the material encountered, and cannot be regarded as showing the capacity of the dredge while at work on submerged bars of channel sand.

The composition of the bar above water and to a depth of 7 feet below was pure sand, but below this, and probably extending to the depth reached by the suction pipes, was blue mud. Had the suction pipes been raised above this mud the amount of material moved would undoubtedly have been much larger. The total volume moved was 40,991 cubic yards, or only 652 yards per hour. As this dredge is identical in size and construction with the "Epsilon," the difference in amount of 1305 and 652 yards per hour probably represents the difference in capacity when handling the two different materials, sand and mud.

COST.

It is manifestly impossible to give any approximate cost of moving the material per cubic yard, as it is impracticable to ascertain with any degree of accuracy the amount of material moved. The surveys of the ordinary crossing, made before and after dredging, give results as a whole, but do not indicate the amount of

material moved by the dredge alone. In one case the river may have been almost on the point of breaking through a bar, and needed only that a start be made by a dredge to encourage the current to complete the channel. In this case the amount of material moved by the dredge may have been a small part of the total amount moved in opening a channel. On the other hand, a cut may be so located that it is constantly being filled by the current, and in this case the amount moved by the dredge is greater than appears.

A computation was made of the cost per yard handled during the tests. This cost includes fuel, payroll, subsistence, lubricating and lighting supplies, and any small repairs made during the time occupied in testing. It does not include any allowance for cost of plant, towing to point where test was made or cost of steam tender. The average cost for the three dredges first mentioned was 85-100 of a cent per cubic yard.

The total cost of operating five dredges during the low-water season of 1898, comprising a total time for one dredge of 403 days, and extending from September 3 to December 23, was $92,052.89, and, including surveys, general superintendence and inspection, $120,272.76, or an average of $225.93 per day per dredge for the operating expenses alone, or nearly $300 per day including all expenses connected with dredging operations.

As a matter of curiosity, the writer has determined the total amount of material moved during the season, assuming that the dredges during the time of actual dredging were handling 90 per cent. as much sand per hour as was handled during the capacity tests. The total is something over two and one-half million yards, or at a cost of a little less than 4 cents per yard for operating expenses for the season. These figures, it is understood, are based on mere assumptions, and have no value except to give a very general impression of the magnitude and cost of the operations.

THE RESULTS OBTAINED.

The year 1898 was not one of extreme low water, as the lowest reading was 7.7 on the Cairo gauge. This does not, however, necessarily indicate that there was proportionally more water in the channel than during extreme low-water years, for the season was one of constant fluctuations; and this condition, as is well known, tends to produce less water over the crossings than does a slowly falling or stationary river, even though the stage reached may be considerable lower. At no time during the season, as far as I know, was there less than 8½ to 9 feet in the channel below Cairo, which is more than for several years previous. How much of this was

due to the dredges can only be surmised, but I think no one will deny that they are entitled to some of it, for at no time did a dredge, attacking a bar, fail to open a channel with 12 to 13 feet of water; and this channel, if properly located, was maintained without further work as long as the river continued to fall or remained stationary, though it was very likely to be partly obliterated by a rising river.

The operations during the season of 1899 have, I understand, been even more successful, as the river then reached a much lower stage.

The proper location of the dredged channel is the most important feature in connection with the success of dredging operations. If properly located, the river will assist in making the cut, and, in fact, in many instances, as mentioned, the action of the current scours out more material than is actually handled by the dredge, a start having been made by the latter.

On the contrary, if the channel be improperly located it is impossible to keep it open. No rule can be laid down for these locations, as they depend on the conditions at each bar, and success is acquired only through experience and a careful study of the movement of the channel under various circumstances.

WEAR IN OPERATION, AND REPAIRS.

The dredging season usually lasts from about the first of September to the middle of December. During the remainder of the year the dredges are cared for by a small force, and the necessary repairs are made by this force as far as can be done with the appliances on the fleet. The various kinds of machinery on the dredges, consisting of boilers, engines, pumps and hoisting and hauling engines, have been so proportioned for the work they perform that the wear and repairs required are not more than that of machinery of this kind in other use, and need not be considered here. The wear of the main sand pump is, however, a very serious matter, and to this point attention is invited.

During the dredging season of 1898 the casing on the "Epsilon" was worn by the action of the sand, so that in the lower half of the casing on the port side a slit about 18 inches long was worn entirely through. This was repaired while in the field by riveting a plate of boiler steel over the hole and on the inside of the casing. The three accompanying figures show the wear on the pumps on the "Epsilon," the "Zeta" and the "Gamma" at the end of the season. The metal of the casings on these pumps was originally 2 inches thick. The "Epsilon's" pump had been run

about 1063 hours, including the time occupied in capacity tests. The "Zeta's" pumps had been operated about 760 hours.

The casing for these pumps is made in two castings, joined along a horizontal section line, and no provision was made for any adjustment for wear. It is manifestly impracticable to renew the entire pump casing with only about forty-one days' use in actual dredging, and they were repaired as shown. A circular section, 40 inches in diameter, was cut out of each side; the edge of this cut and the outside surface of casing for about 3 inches back was faced up. A casting was then made, which bolted to the flange of the elbow on the suction pipe and to the casing of the pumps, as shown. To the inside of this casting were bolted the wearing rings, as shown; the inside face of the casing, beyond the section cut out, was faced up and lined with flat plates which are in four pieces. As these plates are sectors of circles, and have a dish to them, owing to the inclination of the pump casing from a line perpendicular to the axis, their construction was not a simple matter. The pump casing was, of course, cut and faced up in place. The runner and its shaft were removed. The runner shaft forms a part of the main engine shaft, and has a flange coupling on each side between the pump shell and the pillow blocks.

The following device was used for cutting and facing the casings: A 7-inch shaft was turned up and supported in temporary wooden babbitted bearings, the center of this shaft, of course, being exactly on line with the main shaft. This shaft carried a cast iron arm firmly bolted to it; the arm had V's cut on it, normal to the line of the shaft, corresponding to the V's on the carriage of an engine lathe. It carried a compound tool rest taken from an 18-inch lathe on the dredge, and was supplied with the necessary feed screw. Motion was given to the shaft and arm through reducing gearing and a counter-shaft belted to a small engine set up in proper position for this purpose.

The inside surface of the new lining was placed somewhat inside the original lines, to compensate for the wear on the edges of the runner blades. The most serious feature of this excessive wear is not merely the expense of replacing a certain amount of cast iron, but the loss in the efficiency of the pump. The efficiency is lowered very rapidly as the clearance between the runner and the casing increases.

I am told that an observation made in 1899 shows that with the increase of the original clearance from $\frac{1}{8}$ inch to 1 inch, the combined suction and discharge head at the same speed was reduced 50 per cent.

Lines on the figures show the wear in the new liners during the season of 1899.

The actual time of dredging was, for the "Epsilon" 794, and for the "Zeta" 546 hours.

The deep grooves in these lines are explained by the fact that during the season of 1899 some experiments were made with a rubber covering to the runners, which extended somewhat beyond their edges to reduce the clearance. These covers were held in position on the runner blades by bolts passing through a ½-inch iron strap on the outside of the rubber and normal to the length of the blades.

Sand, in passing through the pump, passes along the face of the blade of the runner, and in a direction parallel with their length. A part of this sand was deflected by the iron strap projecting above the face of the blade, and was directed against the side of the casing, where it acted as a sand blast, with the result as shown. Evidently the runner blades should have no projections on their faces which will tend to deflect the sand.

The throat of the pump on the "Gamma" has a curve of much larger radius than on the "Epsilon" and "Zeta," but was badly worn, as shown.

I am unable to account for the wearing into grooves, as it occurred before my acquaintance with the dredge began. The wear shown represents that during the season of 1897, which, including tests, amounted to 600 to 700 hours' actual dredging. During the season of 1898 the casing was protected by wrought iron plate liners, as shown. The clearance in this pump had become so large that cast iron liners were placed in the casing, as shown, without facing it up. The lines on this figure also show the wear in these liners during the season of 1899, which covered a total time of dredging of 576 hours.

The pump on the "Delta" has a casing rectangular in plan, and has a single suction only. The casing seems to wear much less than the others, and, furthermore, the casing was originally lined throughout; and, as the lining consists simply of flat plates, it is easily replaced.

Experience indicates that the entering material receives a rotary motion some distance back of the throat, and it would seem that the amount of wear in the throat might be lessened if this was broken up.

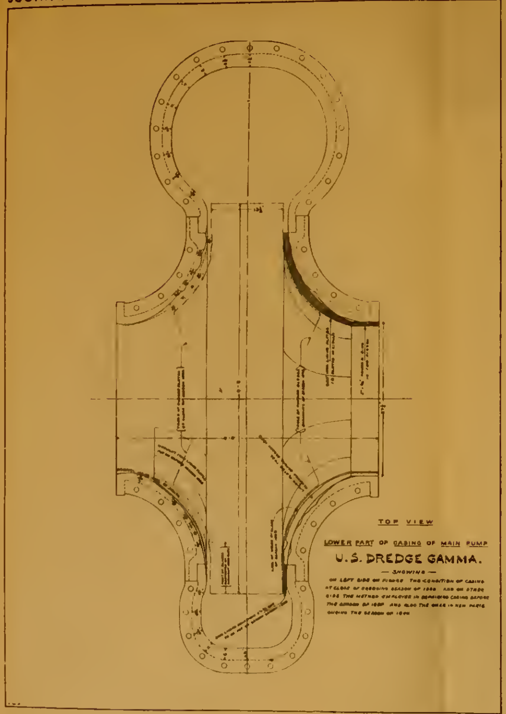
Steps were taken for fixing baffle plates in the suction elbows, but, unfortunately, they were not applied last season, and we do not know what their effect would have been.

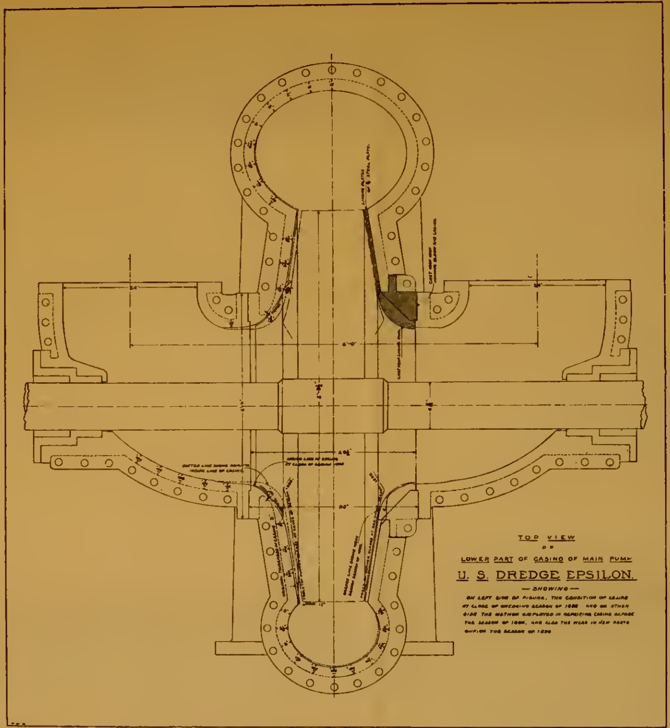
It is also quite clear that renewable liners to the pump casings are an absolute necessity.

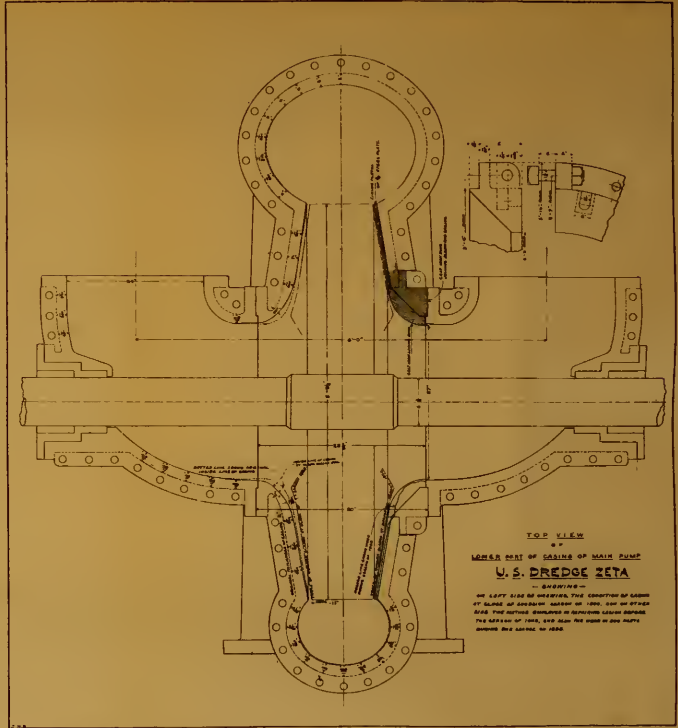
Some method of reducing the wear between the edge of the runners and the casing is also evidently quite necessary. I am informed that several experiments are now in progress, which it is hoped will assist in solving the problem last named. One of them is the construction of an inclosed runner similar in principle to those now used by manufacturers of sand pumps of smaller sizes.

The wear in the throat is also dependent, to a certain extent, on the speed of the pump, speed, in this connection, referring to the number of revolutions per minute and not to the linear velocity at the circumference of the runners. It would seem, then, that the wear might be reduced by lowering the number of revolutions per minute, and, if necessary, increasing the diameter of the runners.

In addition to the repairs on the pump casings mentioned, the interior of the hulls of the dredges and the pontoons and discharge pipes were cleaned and painted. In cleaning the iron work a sand blast was used, and this proved most satisfactory in operation and efficiency.


TOP VIEW
LOWER PART OF CASING OF MAIN PUMP
U. S. DREDGE GAMMA.
— SHOWING —


TOP VIEW
OF
LOWER PART OF CASING OF MAIN PUMP
U. S. DREDGE EPSILON.
— SHOWING —


TOP VIEW
OF
LOWER PART OF CASING OF MAIN PUMP
U. S. DREDGE ZETA
— SHOWING —

THE WATER SUPPLY OF NEW ORLEANS.

By Prof. John M. Ordway, Member Louisiana Engineering Society.

[Read before the Society April 9, 1900.*]

It has been suggested many times that New Orleans might obtain an abundance of good water from one of the clear rivers of Eastern Louisiana, but when close calculations are made, after getting all the requisite data respecting quality, quantity, distance and possible places of storage, I think it would be found that the needed expenditure would be greater than our people are willing to make.

As to artesian wells, it is known that under our city are two considerable sheets of water under sufficient pressure to rise a few feet above the surface. One, about 750 feet down, is too alkaline and too highly colored for general use; the lower one, at the depth of about 1350 feet, is about two-thirds as salt as sea water, and very hard; and, though the liquid when it first comes to the air is perfectly clear, it quickly becomes turbid with oxide of iron. What there is further down we know not, and it is of little consequence, for we should hardly be willing to bore large holes much deeper.

It would not be worth the while to go far from the city to tap underground sources that might possibly be better.

But whatever may be the result of investigations made hereafter respecting waters underground or above ground, near or far off, we must, without interruption, have water in the immediate future; and for this it is likely that we shall continue to depend on the clouds and the Mississippi River. As rain water is soft, and therefore much better for washing and cooking, it is not best to discontinue its use whenever there are cisterns and clean roofs. For other purposes the river will afford an unlimited quantity, and by proper treatment its quality can be made superior to the average of what is supplied to the other cities of our country.

The water of most rivers, for a part of the year at least, needs purification by subsidence and coagulation and filtration. That of the Mississippi requires all three throughout the entire year. Even in the rare conditions that prevailed last October and November, when the quantity of suspended matter was almost imponderable, the water was still a little opaline. The river water always contains in solution the carbonates of sodium and calcium and magnesium, and chloride of sodium, with a trace of sulphates and probably some silica, the sum of all not exceeding what is allowable or

*Manuscript received April 23, 1900.—Secretary, Ass'n of Eng. Socs.

even desirable for drinking. In suspension there is more or less dark-colored sand and very fine clay. A portion of the clay is in an intermediate state between suspension and solution, and, like some other substances that chemists occasionally meet with, it will pass through a paper filter and it will not subside in any reasonable time. The alkaline carbonate appears to promote the quasi solubility of this aluminum silicate, though neutralization with a stronger acid fails to effect a precipitation. But it is well known that there are chemicals that have a specific power of changing the condition of the colloid clay so that it will subside readily, or can be filtered out with great rapidity.

In the case of coagulants we are restricted by considerations of cheapness and harmlessness to lime, ferric salts and preparations of aluminum. Lime, when used in the right proportion, combines with the carbonic acid that tends to hold the carbonates of calcium and magnesium in solution, and the resulting carbonate gradually settles, carrying with it a part of the calcic carbonate originally present. So the temporary hardness may be temporarily diminished by lime, but the subsidence is too slow; and even after twenty-four hours' standing the water is not absolutely clear. Carbonate of calcium precipitated from a cold solution is light and flocculent at first, but after a while it becomes dense and crystalline, almost like sand; so it has little entrapping power.

Alumina combines chemically with organic matters and with soluble silica; the precipitates are flocculent and adhesive, and they can carry down with them much suspended matter. But the condition in which the alumina is presented to the waters is by no means a matter of indifference.

More than forty years ago* I made a rather extensive series of experiments on the basic salts of the sesquioxides merely for their scientific interest, not finding at the time any practical use for them. Latterly, as a friend was speaking of the wonderful clarifying power of hydrate of alumina, it occurred to me that the hydrate brought into solution might be more efficient than the gelatinous preparation. Accordingly some bibasic chloride was made by dissolving in the normal chloride as much alumina as it already contained. And when some of this was added to our brown artesian water it acted almost like magic. While a normal salt, like alum, requires six hours or more to throw down the humus completely, the bibasic chloride effected a perfect clarification in six minutes. For that particular water, therefore, this basic chloride is the ideal precipitant.

**American Journal of Science* for 1858, XXVI, p. 197.

The question naturally came up whether there is any simple coagulant that will answer as well in other cases. Hundreds of experiments have been made during the last two years on our river water, and almost every safe thing that could be thought of has been carefully tried, but so far humic acid has proved to be much more tractable than clay. Certain iron and aluminum basic salts effect the chemical changes just as quickly, but the mechanical subsidence of the precipitates is much slower. Ferric hydrate has not so strong chemical affinity for the impurities as the hydrate of alumina, but, on the other hand, a ferric precipitate is much heavier and denser than an aluminum combination; and, moreover, iron preparations are cheaper than those of alumina. When we unite the two kinds, while the aluminum part insures thorough action, the iron hastens the settling. And such a mixture has come the nearest to giving complete satisfaction. It is a singular fact that when a basic combination is made which contains less than two atoms of aluminum for every atom of iron, the mixture does not keep well; the ferric oxide sooner or later undergoes a change, and the liquid becomes turbid and less active. The preferable compound is found to be a liquid in which there are two molecules of bibasic aluminum chloride for one molecule of bibasic ferric chloride, or, as the chemical equivalent of iron is a little more than twice that of aluminum, we may say that the actual weights of the two metals in the combination should be equal. The coagulant of known strength being provided, it is easy to determine by tentative trials the exact amount required to do the work. We may dilute some of the liquid with pure water, so that it shall contain 3.55 parts of chlorine in a thousand. Then into each of several glass jars we put a liter of the water in question and add to No. 1 one cubic centimeter of the test liquor; to No. 2 two cubic centimeters, and so on; stir them well and allow to stand a few minutes. The jar that coagulates completely with the smallest number of cubic centimeters of the test liquid indicates, with a little calculation, the proper amount of coagulant to be used. A liter of the Mississippi water as it passes our city usually requires fixe or six centimeters of thé test liquor. And, as far as my experience goes, the amount does not differ greatly at different times of the year, for though the coarser mud varies very much, the clay and the dissolved matters are more constant. For some reason, we know not exactly what, the clarification is not complete until the sodium carbonate is all changed, and so the acid of the coagulant under consideration must suffice to neutralize the alkali. Then the bases combine with the half-dissolved matters and carry them down, leaving the clear

water with only a very slight increase of the small amount of common salt originally present. A little excess of the precipitant does no harm, as the carbonates of lime and magnesia will take care of it.

In operating on a moderate scale—I have tried five gallons at a time, and forty-five gallons at a time—the coagulation is immediate, and 99 per cent. of the suspended matter settles within ten minutes after the stirring ceases. In a few hours the water becomes passably clear, and standing over night renders it entirely free from turbidity and colorless. So when the demand is not very great, by having two cisterns to be used on alternate days, we may get a plenty of perfectly clear water by coagulation and sedimentation only. But for a large city there could hardly be afforded settling room for twice twenty-four hours' supply. It would probably be better to allow an hour for the subsidence of the mud, and then separate by rapid filtration the very slight amount of suspended matter still remaining. The best size and shape of tanks for the preliminary settling have to be determined by experiment. I think it would be well to have a considerable number of them,—twenty or more,—similar to the model which I have here (see drawing). The cylindrical part might be 30 feet in diameter and 25 feet high, and the conical bottom 15 feet deep. The lower portion is made conical to facilitate the automatic discharge of the mud, and I have found that the slope must be one of not less than 45 degrees, to allow the sediment to slide down to the point of exit. Hence the diameter cannot be much greater than I have specified, unless the bottom is made into several cones instead of the simple form of one. The discharge pipe being carried up from the point of the cone to within a few feet of the top of the cylinder, and somewhat higher than the levee, the mud may be disposed of by running it back into the river, as it is not worth saving.

Of course, a preliminary sedimentation necessitates an additional pumping, but this is not so serious an objection as one might suppose at first thought, for, as the crude water is to be raised to an average height of only about 25 feet, not very much power is required. Then, too, the settlers deliver the water to the second pumps under a head, instead of requiring these to exert a part of their force in suction. And it must be remembered that the first pumps alone have the gritty water to contend with, and therefore the chief wear comes on them, thus saving much to the far more costly high-pressure machines, which have to drive the clear water into the mains and the reservoirs.

Whether there shall be still a third or intermediate pumping depends on the arrangement for completing the clarification. Of

course, the settled water can be forced through high-pressure filters directly into the mains, or the filtration may be effected by a separate operation. I believe in the division of labor, and would therefore, with some increase of apparatus, filter into a receptacle from which the last set of pumps would take their constant supply.

The low-pressure sand filters which are used in Europe and in some places in this country have proved effective in removing bacteria, as well as the visible impurities, but the percolation must be kept slow by regulating the outlet. Hence they must have a very large horizontal area. Such filters for us would occupy several acres of ground,—ten or twelve,—and the basins would have to be paved over the whole bottom and sides. Then the great quantity of sand and gravel needed for the beds must be brought from afar. It has been found that when a coagulant is used higher pressure is allowable, and so the safe rate of working may be greatly increased with a corresponding decrease of filtering surface. Therefore, as we have to apply a chemical precipitant, we may as well save much space and material by expending a little power.

Not having had the means for experimenting largely on the quick removal of the last traces of suspended matter, I have no particular form of apparatus to recommend for this purpose. We should "prove all things and hold fast that which is good." There are numerous patented contrivances for rapid filtration, and, if we can trust the statements of the makers, each of them is superior to all the others.

Inventors do not always study sufficiently all the conditions of the problem to be solved, and they often seem to exercise their wits not so much to find out what is really best, as to get some new kind of inlet or outlet, some more or less complicated fashion of distributing the water evenly over the bed; some modification of the false bottom; some special form of stirrer to be used during the regular running, or in the washing of the bed; the introduction of some pretended specific purifier into the bed itself; some uncommon plan of discharging the muddy wash water, or some convenient method of mixing in a coagulant, the accuracy of the dosing being sacrificed for this professed gain. But novelties are not always improvements, and, in fact, the really essential items are not patentable. Without asking anybody's leave, we may filter downwards or upwards, or sidewise, or obliquely. Washing the filter by reversing the current of water was in use over fifty years ago. No one can lay exclusive claim to any of the materials cheap enough for the bed. There are the granular matters, sand and crushed boneblack, coke, charcoal and metallic iron. Of fibrous substances there

are asbestos, of long or short fiber, glass wool, slag wool, cotton, gun cotton, hair, paper pulp and sponge. In continuous sheets or plates we may have cotton cloth, woolen cloth, felt, paper, porous sandstone, porous pottery and artificial agglomerations of sand, fossil meal or granulated carbon. All have been used; all are good, but all, sooner or later, become clogged and have to be washed or thrown away and replaced by new.

Of all these things, loose sand, being hard, unchangeable, easy to wash and cheap, is most suitable for operations on a very large scale. But it is best fitted for downward filtration, and care must be taken to keep it always evenly distributed over the bed, for it is liable to gully out in spots and leave by-passages that allow the water to flow through unchanged. It needs watching therefore, and the filters should be arranged so as to make the inspection easy at any time.

The purification of our river water is uncommonly costly, and some would advise that for some purposes the crude water be distributed as at present and the purified be conveyed through another set of pipes. Experience in other cites has shown that much additional expense is incurred by careless or wanton waste. Here such waste would fall chiefly on the clear water, and clear water makes up the larger part of what is wanted. If the extravagance can be checked it would be as well to clarify the whole, and avoid troublesome complications. There can be no doubt that even for flushing the gutters and for putting out fires clean water is preferable. Certainly, with this the distributing pipes will retain their full capacity.

It has been found very commonly that the introduction of meters has a wonderful effect in correcting the thoughtlessness of consumers. As for gas, so for water, meters should be put in everywhere, even if it has to be done at the expense of the city. Begin at the outset with requiring or furnishing such checks, and it will create far less trouble than to insist on them afterwards. Of course, there should be a regular inspection of meters from time to time, to see that they register correctly.

Where people in summer open the faucet and let many gallons run off merely to get a half-pint cool enough to drink, and in winter allow a constant flow all night to keep the pipes from freezing, a family takes vastly more than its fair share. But where the water is supplied wholly or mostly by gravity, and needs no special purification, they can afford to be a little wasteful and not restrict by measuring. Here pipe freezing is a great rarity, and water drawn from the underground part of the pipe is not cold enough to

be palatable. And yet perhaps some other excuses may be found for needlessly increasing the consumption, unless there is some restraining power. With reasonable checks fifty gallons per day for each inhabitant ought to be ample allowance, even in our climate, where a free use, but not abuse, should be encouraged.

Allow me to say a few words about equalizing the distribution, something which past experience has shown to be much needed. As the machinist, between the times of heaviest demand, stores power in the fly-wheel, or the hydraulic accumulator, so the water works pumps should, by constant running, secure a surplus in reservoirs of sufficient capacity and sufficient elevation to tide over sudden drafts. We might as well run a force pump without an air chamber as water works without storage places. But our city is peculiarly situated, in that this whole region is raised but a little above tide water, and there is no hilly country within reach to furnish places for naturally elevated reservoirs. The alternative, then, is to build one or many tanks on artificial supports of earth, iron, brick or stone. An earth foundation requires too great a spread of base, and we have no stone. Iron stand pipes could be built at least a hundred feet high, the lower half of which would act merely as a support for the really used upper half. In this case, to have the available portion hold over a million gallons, the lower parts must be of intractable thickness in order to resist the tensile stress at the circumference, to say nothing of the great shearing force acting on the rivets of the horizontal seams. To raise shorter tanks 50 feet high on iron columns would be very expensive. The easier and better way might be to build up high brick walls and arch work. Or there is still another plan, perhaps the cheapest of all, and that is to fill with concrete a vertical iron cylinder whose thickness need not exceed a quarter of an inch, for there would be no outward pressure after the setting of the cement.

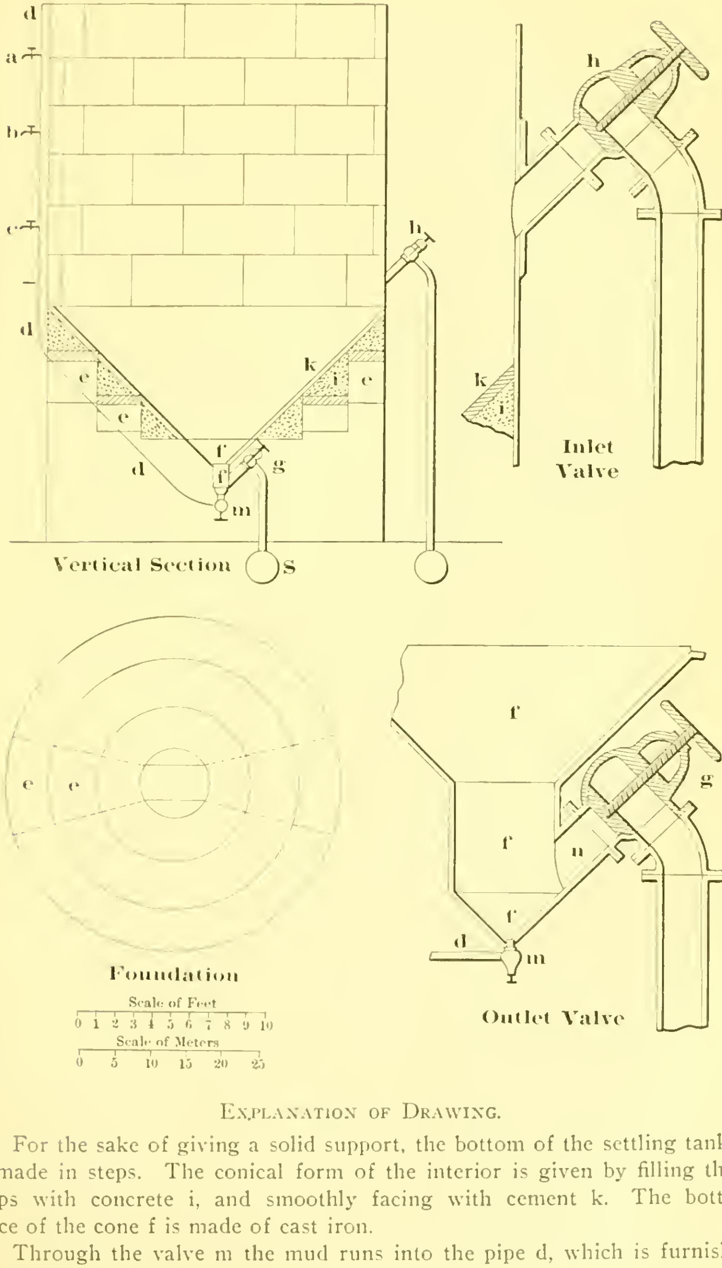
It is true that the capacity of a cylindrical pipe increases as the square of the diameter, while the circumference increases only as the diameter. But when the pipe is to be filled with water, the thickness of the circumference must also increase as the diameter. So, after reaching a large but still manageable size, it would be about as well to multiply the number of tanks instead of enlarging the sectional area. Several elevated tanks 60 feet in diameter and 50 feet deep could be distributed in different parts of the city, so that no place would be more than two miles from one of them. Then the loss of head in supplying a sudden demand at any spot would be greatly diminished. Then, too, the whole of the pumping and purifying apparatus could be placed above the city, where they

certainly ought to be; for, though the drainage on land is mostly away from the river, the ships in port may contaminate the water somewhat.

The scheme which I have thus hastily sketched will hardly strike some of you favorably at first, but on second thought I hope it may be found worthy of consideration and discussion. I would by no means say that the work cannot be done, and well done, by other plans. Thus, instead of using the single coagulant, we could get along with lime and sulphate of aluminum, or lime and a normal ferric salt, provided we use them in just the right quantity and in the right way; and the effect would be nearly as good, and the cost perhaps a little less. In this, as in many other instances, apparently trifling details have an important bearing on the results. Chemicals must be used, and, as the conditions vary somewhat at different times, the constant supervision of a chemist is needed to insure the right quality of materials, the correct proportions and the proper manipulation, for the health and comfort of a large population is at stake. So far as I can learn, no one has heretofore adopted sedimentation at rest between the coagulation and the filtration, and yet I believe this to be a matter of no little consequence. In this way there is a gain in time and facility of getting rid of the refuse. In letting the settling come first there is really no saving of coagulant, and no other advantage.

On account of the peculiarities of our situation, we cannot copy closely what others have done. In the East the ponds and rivers are seldom turbid, and the sources of supply for many cities and towns are so high that gravity can do most of the work of distribution. The cities on the Ohio have to deal with a river that is clear a large part of the year, and coal there is very cheap. At St. Louis they have always the muddy Missouri, not yet fully commingled with the clear waters of the upper Mississippi, the Illinois and now of Lake Michigan. We have added to all these the drainage of an immense area of very diverse geological formations, the influx of the Wabash, Cumberland, Tennessee, Yazoo, White, Arkansas and Red Rivers each furnishing its special quota of dissolved and suspended matters, and in such a way as to keep up the turbidity of our river all the time. We have much more to contend with than most other cities, and must expect to have trouble and to incur greater expense. We must to some extent strike out anew, boldly but prudently, and be content to proceed slowly, feeling the way as we go. We ought not to be satisfied with any halfway measures, but should never rest till we have a full supply of water, as good as any city can boast of. The prime consideration should be to make a thorough

clarification at any rate, and the next care should be to reduce the cost to the lowest possible terms.



EXPLANATION OF DRAWING.

For the sake of giving a solid support, the bottom of the settling tank w is made in steps. The conical form of the interior is given by filling these steps with concrete i, and smoothly facing with cement k. The bottom piece of the cone f is made of cast iron.

Through the valve m the mud runs into the pipe d, which is furnished with cocks a, b, c, one or another of which may be opened according to the

density of the semi-fluid mass. When it is very thick c will afford an exit, and when it is lighter b or a may be opened. These cocks discharge into a pipe not shown in the drawing, through which the waste flows back to the river.

The outlet valve g, and the inlet valve h are placed on a slant so that no mud will lodge in them during the settling.

The passageway underneath is partly covered by the brick arches e.

The main supply pipe r, and the main exit pipe s may be placed underground, or above ground.

Should the water be found to require a more thorough stirring than it gets during the inflow, air can be blown in through a pipe extending halfway down the cone.

It would not be worth the while for the city to improve the water still further by making it soft, though this can be done by precipitating the most of the lime and magnesia with a mixture of sodium phosphate and caustic soda. Consumers who have a tender regard for their complexion or a desire to save soap can themselves secure a more satisfactory washing water in this way and with very little trouble, for settling over night completes the purification. Were the demand sufficient, the material could be afforded at low price, and then our cumbrous rain water cisterns might give place to conveniently disposed precipitating tanks.

NOTES ON THE RELATION BETWEEN THE GEOLOGY OF THE SOURCES OF WATER SUPPLY AND DISEASE.

BY MARSDEN MANSON, MEMBER TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society April 7, 1899.*]

DURING the past few years the writer has had occasion to visit various parts of the State, and the idea presented itself that it might be desirable to ascertain as far as possible certain facts with regard to the water supply and filth diseases of the various towns. Time did not permit of gathering more than a general idea of local conditions, so the opportunities for getting detailed or extended data were not favorable. The main impressions derived from these notes are presented now in crude form with the hope that interest may be awakened in the subject, and that other members of the profession may extend this examination. At some future time the writer may be able to give the results in more detailed form, and to present features which cannot now be discussed.

The mode of procedure was simple, and consisted in an examination of the supply, closely questioning those in charge and visiting and questioning the local physicians, who in all instances gave valuable information. To these gentlemen, and particularly to the physicians, the writer is much indebted. It soon became apparent that there was a certain recurrence of special types of disease in widely separated localities, and that some similarity in the water caused this recurrence. Certain diseases not especially recognized as water borne were first noted. Water-borne diseases are notably from organic contaminations, and sewage influences dwarf all other sources of contamination; yet the cumulative effects of mineral impurities cannot be neglected.

The geology of the source determines the nature of these impurities, and influences the mode and rate of organic contaminations; it therefore becomes an important factor in water supply. It has long been known that a deficiency of bicarbonate of lime in domestic water was not desirable for infants and growing youth, which deficiency has to be remedied by the addition of lime-salts to give sufficient material for bones and teeth; also that this water was desirable for adults and elderly people, instances of this are Portland, Ore., and Glasgow, Scotland. An excess of this salt can readily be utilized or eliminated in youth, but induces certain dis-

*Manuscript received April 23, 1900.—Secretary, Ass'n of Eng. Socs.

eases of the joints and urinary organs and the deposition of lime in the tissues in middle and later life.

Between these wide extremes there are many delicately balanced conditions not always readily recognized, but becoming apparent after long use when carefully studied. In many parts of California water is too dear a necessity to criticise from a sanitary standpoint, unless it is so dangerous as to cause an excessive death rate; and even then most communities are content to await the fortunate return of favorable conditions rather than incur any expense in correcting the evils. Again, the diseases are sometimes so insidious that they become apparent only to the observing physician of long practice. Interesting instances of this will be given later.

It will be necessary also, before taking up special types, to refer to the very marked difference between the geology of the Sierras and that of the Coast Range, and of the influence of this difference upon the water from each. The Sierras are principally granites, syenites, the harder slates, silicious rocks and insoluble lavas. The Coast Range is composed of much softer rocks, which contain more soluble mineral matter, particularly salts of magnesia, soda, lime, alumina, etc. These differences are further intensified by the greater precipitation upon the Sierras having leeched out the soluble salts and cut down the streams into harder materials. In each range there are also localities which partake of the nature of the other; thus the northern and central groups of the Coast Range are granitic and yield waters resembling those of the Sierras, and portions of the Sierras yield waters in which there is an abundance of mineral salts.

These differences in geological formation give rise to marked differences in the waters from the two ranges, those from the Sierras frequently having as low as five or six grains of mineral matter to the gallon, and those from the Coast Range sometimes contain ten to forty times this amount.

Apart from organic contamination, these latter waters, when highly charged with mineral salts, produce after long use certain types of malnutrition and indigestion, inflammation of the kidneys and bladder, and if deficient in lime, as is sometimes the case, young people, and even children, lose their teeth.

This latter trouble was particularly noted in Owens Valley, where on one side water fairly abundant in lime occurs and on the other side its place is taken by soda, magnesia and alumina, like some of the Coast Range waters. The dentist practicing in this region gave it as the result of years of observation that his practice was principally confined to middle-aged and elderly people on the

side of the valley in which salts of lime occurred, but embraced children as young as thirteen years of age on the side in which lime was deficient.

A similar water was encountered in Vacaville. One of the physicians here, upon being asked about the types of disease incident to the water supply, at once came to the defense of the locality as regards malarial troubles, and fully explained that the few cases occurring were due to special conditions or were "imported"; but when asked regarding the occurrence of kidney or bladder trouble, of which he had had severe cases, admitted that he could account for some of these cases only upon the assumption that they were due to the continuous use of water containing an excess of the salts of magnesia, soda, alumina, etc., and to the weakening of these organs in eliminating these salts.

Water from shallow deposits of quaternary and recent gravels and soils are always dangerous; not by reason of their soluble salts, but for the ease with which these formations permit organic contaminations to pass through them. It does not matter at what elevation above tide they occur, distinct types of disease follow them, partly due to the two causes above mentioned. In low elevations malarial fevers predominate. In elevated regions this takes the form known as "mountain fever," the two being, so far as the writer can determine, analogous.

In some instances, as in many of the foothill towns, the purest and best of water is turned out from the streams of the high Sierras and conducted along slow-flowing ditches in surface soils and stored in shallow service reservoirs of recent geological formation, and hence favorable to organic contamination. The result is that persistent cases of low gastric fevers and diarrhea occur every autumn due directly to organic contamination, but augmented by geological formations traversed and utilized. This is the most universal type of abuse of good water that one comes in contact with throughout the State, except the direct contamination of the soil adjacent to surface waters used for domestic purposes.

It is very difficult to convince the general public using these supplies of the evils of these contaminations. No more fertile field is open to the engineering profession than a systematic endeavor to bring before the people simple and practical means of correcting these gross violations of the laws of cleanliness and health. The degree of ignorance and prejudice to be encountered is great, and to be successfully overcome will need the aid of the Universities and of the Legislature.

Water from deep gravel and sand is generally free from dangerous organic impurities, but is likely to be heavily charged with mineral salts; where a change has been made from one source, surface supply, to deep strata or artesian water a change in health has occurred. An attempt was made to trace the effect of this change through the introduction of those diseases incident to an increase of mineral matter, but this attempt was not successful, although two localities were found where the conditions might be considered favorable. Full data for the determination of this interesting point are not now available, and the scattered data which could be given would probably be misleading.

The kindred subject of the great improvement of health by the introduction of better water supply was frequently noted, but is foreign to the immediate subject of these notes.

A marked instance of the influence of the geological formation in affording very favorable conditions for correcting the effect of contamination was noted in Chico.

The case was simple enough when once traced, and really amounted to nothing more than changing the intake of a pipe above the source of contamination, which if occurring above ground would be considered a simple and common sense remedy; but occurring in this case underground, in a slow-flowing broad stratum of water in coarse sand and gravel, and having caused years of sickness and a rich harvest to the medical profession, it becomes of more than passing interest. Besides, it affords a valuable lesson to those whose stupidly set notions will not permit a proper regard for the health of a community to interfere with their income.

The town of Chico is situated on the east side of the Valley of California, near the base of the foothills. The valley slopes gently to the west. The soil is a sandy loam, under which exists a gravelly stratum carrying an excellent quality of water, easily tapped by reason of its uniform distribution, and affording, by reason of the simplicity of the formation, ready means of disseminating contamination.

The water supply was, until some years since, obtained by tapping this stratum at the western or lower edge of the town and pumping it into elevated tanks, from which it was distributed by pipes. Fecal matter was, and is now, disposed of in pits sunk into the porous soil, and when full or clogged up a new pit was dug adjacent to the old. To such an extent has this been carried that in some backyards nearly every part has been contaminated.

As a natural result the water supply in the stratum below became grossly contaminated, and for years the health of the town

was extremely poor. The death rate was not abnormally high, but the occurrence of insidious forms of gastric diseases was excessive. One physician stated that his monthly cash receipts were about \$1800, besides accounts, which were slowly collected or delayed indefinitely.

Finally the intake of the water works, or the pump, was shifted to a new well on the eastern or upper side of the town, and these diseases disappeared as if by magic. The physician whose monthly receipts were \$1800 had a decrease which reduced him to \$800 a year, although he still attended the same percentage of sick which he previously had, only the number of patients which required the attention of the medical profession was reduced by eleven out of every twelve sick. This, as partly explained above, was due to the simple expedient of changing the intake to a point above the contamination, but, being underground and out of sight, it took years to convince the people of the necessity of the change, and in the meanwhile thousands of cases of sickness occurred each year for the want of a common sense view of the geology of the locality and its influence on the rate of pollution of the water supply.

The geological formations of the great Valley of California are very interesting to study, especially in their influence upon the water supply.

The strata of this valley are complex, and are only known from the deep borings made in groups, particularly in the southern half. These when platted show that there is a semblance of stratification, and that the strata alternate in clays, sands, gravel and even cobblestone.

This depression in the crust is filled up in places for more than half a mile with these alternating layers. An approximate estimate of the volume between bedrock and the 400-foot contour above sea level shows that certainly four, and probably six or eight, thousand cubic miles of material has been denuded from adjacent watersheds.

The borings into these strata yield waters of very widely varying character. Those near the surface are generally dangerous, from organic contaminations. Those from a few hundred feet below the surface are ordinarily good.

From depths of a quarter mile, or even less, they are sometimes charged with mineral matter to such an extent as to render them unfit not only for domestic purposes, but even for irrigation. At these depths, however, they hold another mineral ingredient, light carburetted hydrogen, in such abundance that it is collected as natural gas in Stockton and Sacramento, and largely controls the price of fuel and light in these cities.

A very abundant class of waters cannot be more than briefly referred to,—namely, "mineral" waters. These are numerous, and of great variety; some highly valuable for medical properties, others useless, or even dangerous. The springs occurring along the great fault from Kern County into Nevada and Oregon and others near faults or recent lava outbursts are frequently hot or boiling. They are sometimes charged so highly with mineral matter that their use, except for periodic bathing, is limited. All of their ingredients and temperatures are controlled by the geological formations in which they occur. The general conclusions were that not only do the geological conditions influence the medical value of waters, but that they have a deeper interest to the engineer, in that they directly and indirectly influence the sanitary value of the water.

Directly by charging the waters with small quantities of certain salts injurious to the human system when continuously used, and by the absence of salts of lime depriving the system of an ingredient needful in early life.

Indirectly by affording conditions which render organic contamination more or less easy to accomplish.

These conclusions, it may be said, could have been predicated before and for any area, but their local application over so broad a field as California is an interesting and useful study, and one which warrants your best efforts. It is by no means as important as the removal or suppression of organic impurities, but it is nevertheless an issue of considerable moment and one the engineer cannot afford to overlook.

SEA LEVEL CANAL ACROSS THE ISTHMUS OF SAN BLAS.

By Wm. W. Redfield, Member Engineers' Club of Minneapolis.

[Read before the Club April 23, 1900.*]

In 1889, on the 8th day of May, the author had the honor of reading a paper entitled "San Blas Canal *versus* Panama Canal, and Sea Level *versus* Locks." In that paper (published on page 345 of Vol. VIII of the Journal of the Association of Engineering Societies) he endeavored to state clearly the superiority of the location at San Blas over that at Panama, and also over that at Nicaragua, on the ground that "sea level or nothing" (as the lamented de Lesseps himself declared) is the one thing needful to seek after. Such being the case, it follows that the Nicaragua route becomes necessarily excluded from consideration, for it is conceded by all that nothing but a lock system is possible for that route. This limits the discussion to the Panama route, and also to the route that is the subject of this paper,—to wit, the San Blas route, whose Pacific terminus is about 30 miles due east of the city of Panama.

Locks intrinsically are expensive. They necessitate a summit level that must be constantly supplied to full capacity with feed water. In their use considerable loss of time is incurred. On the other hand, a sea level canal requires an enormous quantity of excavation. This, however, is simply a matter of cubic yards, generally of rock at the deepest part of excavation through the backbone ridge or divide. Yet, when completed to sea level, no loss of time ensues other than that due to formal delays in entering and leaving the canal and in passing the tidal locks, and also to the necessary slackening of speed in the passage.

Now, if sea level is so desirable, it is proper to ask, "What is the matter with the Panama route, only 49 miles long, having a maximum altitude of less than 400 feet above sea level?" In reply, I would say that, in spite of these apparent advantages, newspaper reports, amply corroborated, have made us all aware of the floods from the Chagres River, largely undoing work as fast as it progresses. The line of canal closely follows the Panama Railroad, and crosses the Chagres River and the Rio Grande many times. It is clearly seen how difficult it is to control these rivers, especially when the canal becomes excavated *below* the present bottoms of these rivers. As we all know, the present plan is to abandon the

*Manuscript received May 14, 1900.—Secretary, Ass'n of Eng. Socs.

sea level project and have locks, with a summit level of 125 feet altitude, for a length of 21 miles. It is now claimed that on this basis the canal can be completed for a less amount of money than the sum already expended. And now comes the very point on which I advocate the San Blas route. This, I will show, can be completed on a sea level basis for less than the sum necessary to complete the Panama canal on a lock system basis.

To present the merits of the San Blas route with comparative clearness I now rewrite a part of my previous paper on this subject. The San Blas route, whose Pacific terminus is only about 30 miles due east of the city of Panama, has been rarely mentioned, on account of just one objection. This is a tunnel seven miles long. But *what* and *where* is this route? Let us examine it briefly. I have the honor to refer to the eminent W. W. Evans, in an article by him on the subject, from which I quote:

"I will confine myself to three predictions: First, that the de Lesseps canal, as a sea level canal, will never be built; second, that the Nicaragua canal will be built, and by our own Government or people; and, third, that when the great importance of this water line to the world, and more particularly to our world, is once proved by the Nicaragua canal, then there will be a sea level canal built on the San Blas route, *where it should have been built in the first place.* It presents the *shortest route from ocean to ocean;* it can be *cut in one straight line, without a curve;* it is *not on a line of drainage;* it has *good harbors at each end;* it *can be traversed in less than one day;* it is *in a comparatively healthy region;* it has *every point in its favor but one,*—namely, a tunnel big enough to pass a ship. And it has not yet got through the craniums of those wise men who have been sitting on this problem for so long a time, trying to hatch out something, that it is as easy to cut a ship tunnel as to cut a railway tunnel; they only differ in quantity. And, as regards this very tunnel, there is not as much rock to be removed as there was in the 'Des Aquadero,' near the City of Mexico, which the Spaniards cut merely as a precaution nearly two hundred years ago, when their tools, their blasting compounds and their engineering knowledge were a mere bagatelle to what we now have at command."

I will now give a little information derived from an article in *Van Nostrand's Magazine* of June, 1869. A survey of the route was made in 1863, and a report in 1864, on behalf of Mr. Fred. M. Kelly and others, of New York city, under the direction of A. McDougall, of Massachusetts, now deceased, as chief engineer, and Charles A. Sweet, of Syracuse, N. Y., as principal assistant. According to

this survey, the length of route from coast to coast is 30.03 miles. It extends from Chepillo Island, on the Pacific coast (about 30 miles east of Panama), to the Gulf of San Blas, on the Atlantic side. For convenience, the work may be divided into four sections.*

Section 1 extends from Chepillo Island to "Paneas," on the Bayano River, and is 10.101 miles long. Work required—a composite dam across the river at the Great Bend of the same; a tidal lock at the Great Bend, with walls 45½ feet high; a short canal cut across the Bend; removal of sandbars in Pacific harbor and in Bayano River, and a lighthouse at Chepillo Island. Estimated cost, including draining, chopping, earth and river excavation, embankment, masonry, labor, materials, etc.:

Removal of bars	$136,684
Lighthouse	12,000
Tidal Lock	675,844
Composite dam	174,631
Great Bend cut	209,835
Total	$1,208,994

Section 2 is a canal from Bayano River, at "Paneas," to the south end of tunnel, and is 8.996 miles long. The work consists of the canal proper, and a new channel for the Mamoni River (crossed by route of canal), about 3.6 miles long. Estimate of cost:

Canal, inclusive of bailing, draining, chopping, excavation, embankment, puddling, etc.	$13,033,943
New channel for Mamoni River	115,752
Total	$13,149,695

Section 3 is a tunnel through the Cordilleras 7 miles long. This is exclusively rock excavation. It consists of a canal of 25 feet depth of water, a perpendicular excavation of 29 feet above water surface on either side, from which springs an arch, forming the roof, and sufficiently high to pass over and clear the tallest masts. This section, at $2.50 per cubic yard, is estimated at $29,316,067.

Section 4 extends from the north end of tunnel to 25 feet depth of water in the Gulf of San Blas, on the Atlantic side, and is 3.073 miles. The work consists of the canal proper, a lock with 9 feet

*The map appended hereto is from the "Reports of Explorations and Surveys to Ascertain the Practicability of a Ship Canal between the Atlantic and Pacific Oceans by the Way of the Isthmus of Darien," by Thos. Oliver Selfridge, Commander U. S. Navy, Washington, D. C., 1874.

fall and walls $38\frac{1}{2}$ feet high, and a lighthouse on San Blas Point. Estimate of cost is:

Canal	$11,234,318
Lock No. 2 or lift-lock	506,017
Lighthouse	12,000
Total	$11,752,335

SUMMARY.

Section 1 equals	10.101	miles at an estimated cost of	$1,208,994
" 2 "	8.996	" " " "	13,149,695
" 3 "	7.000	" " " "	29,316,067
" 4 "	3.073	" " " "	11,752,335
Total equals	29.170	" " " "	$55,427,091
Engineering and contingencies (10 per cent.)			5,542,709
Medical and military aid, etc., interest on capital during construction and transportation			32,500,000
Total			$93,469,800

This estimate is based upon a canal having (except in tunnel) a surface width of 143 feet; at the bottom a width of 100 feet, and 25 feet depth of water. A second and cheaper estimate, on a smaller size of canal, is also given, which I shall not here repeat. Summed up, the general facts are: Entire route, except near the mountains, is nearly level; summit of Cordilleras varies under and over 1200 feet above the sea; entire canal to be fed from Pacific Ocean, and water maintained at the level of ordinary high tide on the Pacific side. Tides on the Pacific side rise from 12.65 to 22 feet for highest. On the Atlantic side there is from 1 to $1\frac{1}{2}$ feet from ebb to flow.

In an article in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for August, 1886 (Vol. V, pages 367 to 382), it is stated that an approximate estimate of work done on the Panama canal and work still to do to complete the same in eight years (1894), in total, amounts, in round numbers, with interest on same, to $800,000,000. Now put these figures (amended by a lessening of amount to suit the transformation of basis from sea level to lock system) against the preceding estimate for the San Blas route, and there is no doubt as to the best route. Take, *alone*, Mr. Evans's reasons, "that it is *not on a line of drainage;* no Chagres problem to contend with; a good harbor at each end" [the Panama terminal harbors have been artificially constructed (1900)], and these, coupled with his other reasons, are sufficient to favor the San Blas route.

And now what about the chief objection to said route,—to wit, a tunnel large and tall enough to float the largest ships? Is that enough to condemn a route when every other argument is in its favor? Has not the science of tunneling advanced to such an extent in the last half-century as to overcome most obstacles? Then, too, the work in tunnel is admirably suited to a tropical climate, because work can be uninterruptedly performed in all weathers. A temporary auxiliary railroad can easily be provided to haul tunnel contents to either end for filling. The map herewith shows a stream crossing the line of tunnel in a depression between two ridges of the Cordilleras. This possibly might be utilized to generate electricity for lights to be placed in tunnel when completed. The head above the canal is sufficient to give the power to a small turbine placed in a shaft sunk to one side of canal, and receiving water through a pipe from said stream and passing same in pipe down shaft to turbine, and then outletting the tail race pipe into canal, thus generating the power to drive dynamos for the electric light in tunnel.

The "line of no drainage" is all-important, even if the divide has an altitude of 1142 feet above the sea, instead of less than 400 feet, as on the Panama route. The greater quantity of dry excavation, or at least the non-interference of any such river as the Chagres, will, I am sure, be found far less expensive totally than a ridge of half that altitude, but reeking with moisture, and, as work progresses, to far *below* the level of adjacent rivers that *must* be taken care of, and whose elevation is far above the canal; and the danger ever present of sudden floods (peculiar to the rivers of the isthmus), driving every barrier away and undoing in a few minutes the work of many months.

With the political phases of the question I think the engineer has but little to do. Still, we may not ignore them, for political reasons and urgencies point out very clearly the comparative merits of various routes. For instance, in our late war with Spain, when our fine vessel, the "Oregon," was beating her own record from the Pacific, through the Straits of Magellan, to reinforce our gallant navy in the Caribbean Sea, and running the danger of encountering the Spanish fleet of Cervera, thousands of miles would have been saved, as well as valuable time. One day would suffice for passing through the sea level canal of San Blas. A longer time than one day would be required for a Panama sea level canal; still longer for a Panama lock canal, and longer yet for Nicaragua. Even admitting that Nicaragua is a longer route, and that three or four days might be necessary there, compare even the Nicaragua

route with the longer journey around South America, and none could deny that we must have a canal of some sort. I am very hopeful of the commission now investigating by surveys of territory contiguous to all three routes. If their work is properly done (and I believe it will be) data may develop that may produce and show clearly a better route; that is to say, the San Blas route, or even a better one not far from same. The commission, I understand, will spend some time at their labors, and when finished the result of their topographical researches will be awaited with great interest and eager expectations.

I will now give some extracts from an article germane to the subject appearing in the *National Geographic Magazine,* of Washington, D. C., by Robert T. Hill, of the United States Geological Survey. The article is entitled "The Panama Canal Route," and is found on pages 60, etc., of Vol. VII of the above magazine. I will confine my quotations from this article to Mr. Hill's statement of reasons why the Panama route is more feasible than that of Nicaragua, and then state his comparative estimated costs, in tabular form, of each route (assuming the Panama route to have the lock system). And, while quoting his table, I propose to parallel the same with the figures just shown in favor of the San Blas route on a sea level basis, and in spite of the fact of the tunnel 7 miles long:

"In the meantime, what are the principal facts concerning the feasibility of the Panama route?

1. "It is the shortest of all, being only 42½ miles from sea to sea, across about 20 miles of which the canal has been completed to 28 feet below sea level, making the actual present distance between the two oceans less than 25 English miles, or about one-seventh of the actual distance (170 miles) to be overcome between Greytown and San Juan, in the case of the Nicaragua route." (The San Blas route is only 29.17 miles long.)

2. "It is the only possible tide-water route in the whole isthmian region. To accomplish this it would, it is true, require great engineering and constructional feats, but in no respect impossible ones." (The San Blas route, only 30 miles to the east of Panama route, can be constructed, whether the 7 miles be in open cut 1150 feet deep or in tunnel, without any serious engineering gymnastics by adopting cantilever tilters, etc., such as have been used on the Chicago drainage canal and other large works.)

3. (As this paragraph mentions the feasibility of the Panama canal for a lock system, I will merely remark that that is the case with the Nicaragua route; whereas on the San Blas route locks are

not only not necessary, but probably impossible, on account of the uncertainty of feed water.

4. "It is in a region comparatively free from seismic disturbance, and one in which no volcanic action has occurred since late Tertiary time. The Nicaragua route is within a zone of topographically destructive volcanic disturbance, where earthquakes are frequent." (The San Blas route is on a par with the Panama route in this respect.)

5. "It has what no other route possesses, excellent terminal harbor facilities, with anchorage at both oceans so improved that ships can enter and leave at will." (San Blas route has them, too, provided by nature.)

6. (As this paragraph deals with the minuteness with which the Panama route has, by this time, been surveyed, I would state that the United States commission, before their labors are completed, will have in their possession facts and data covering the entire extent of country from Panama to San Blas and beyond, and all parts of the isthmus where a canal might be possible.)

7. (This paragraph speaks of the Chagres problem, etc., but on the San Blas route there is no such problem.)

8. "It will be the cheapest route to construct. The plant already furnished, with two-fifths of the excavation now completed for a sea level route, including expense of administration and machinery, has actually cost $150,000,000. Upon this basis it is estimated that the entire length of 42½ miles will cost $116,000,000 more upon the lock level plan. A sea level route would cost $200,000,000 more. The amount of work necessary to complete the Panama canal is far less than would be required to construct the Nicaragua route. Engineers admit that 40 miles of excavation—almost equivalent to the entire length of the Panama canal—are necessary along the rival route. What the cost of the construction of the Nicaragua route will be can never be told until the actual work is well under way." (The foregoing figures unerringly point to the San Blas route as being the cheapest sea level canal that could be built,—$93,000,000, according to the estimate hereinbefore shown.)

9. "It is nautically the most important route, being more centrally situated relatively to the two continents. Its Caribbean terminus is as near by sailing and steaming routes both to the North Atlantic and European ports as is Greytown, while its Pacific terminus is far more convenient to the South American trade." (The San Blas route is practically no longer than the Panama, from continent to continent, located, as it is, about 30 miles due east of

Panama, thus making the total voyage route the same by either route.)

10. (This paragraph, being purely political, is not considered in keeping with this paper, which deals only with the scientific and engineering points of the subject.)

I now append, from the foregoing article, a table, and to this table I add a third column, in order to give significance to the salient advantages in favor of the San Blas route:

	Nicaragua. Lock System.	Panama. Lock System.	San Blas. Sea Level System.
Natural distance, sea to sea, ...miles...	169.5	42.5	29.17
Present distance, sea to sea, ...miles...	169.5	25	29.17
Natural altitude, continental pass, ... feet	147	260	1142
Same as reduced by artificial cutting, ...feet........	147	246	1142
Miles of river course, Caribbean side...	111	31	0
Miles of river course below site of proposed dam........................	32	21	0
Proportion of above diverted by artificial cutting, ...miles	0	10	Nominal, on Pacific side.
Proposed height, summit level, ...feet	110	125	0
No. of dams to create summit level......	1	1	0
Miles of summit level navigation.........	144.8	12 to 21	0
Number of proposed locks...	7	6	(tidal) 2
Excavation (miles originally proposed)	40.3	42.5	25
Miles excavated completed for lock plan	0	15 to 20	0
Miles of excavation to be completed for lock plan....................................	40.3	10	0
Miles of excavation to be completed for sea level plan..........................	0	0	29 17
Terminal harbors.....................	None.	Completed.	Two good natural ones.
Plant on ground for completion............	None.	All.	None.
Estimated cost to complete canals........	$133,500,000	$116,000,000	$93,000,000

An additional reason for the San Blas route is the fact that it can be built on a straight line from ocean to ocean, certainly a very desirable advantage. Now let us imagine the San Blas route to be fully completed, with the exception of the 7 miles of tunnel. Is it possible that if $29,000,000 is all that stands in the way of puncturing this backbone, that the United States would hesitate on account of that comparatively nominal sum? Leaving interest and extras out of consideration, the combined three sections, other than tunnel, would cost $26,111,024, thus showing the tunnel section to cost but little more than one-half of the whole canal. Besides, being on a line of no drainage, and not inordinately troubled with water, an

open cut (of ample width above the rock portion) could properly be considered as an improvement on the tunnel. What a magnificent example of engineering it would be! Short, straight, on the level of the sea, a "*straight* Straits of Magellan!" No detention from flights of locks, except the tidal locks at each end, indispensable on any interoceanic canal. Simple, direct, cheaper to *entirely* build to a sea level system now (including a tunnel 7 miles long) than to *complete* the remaining portion of the Panama canal to a lock system only; illustrating the fact that sometimes it is wiser to throw away part of a *partially* good thing and replace with an entirely new and good thing that can be built for less cost and give better service than the thing abandoned. I also believe that the straight line feature would safely permit greater speed to vessels in passage; the steering would be easier, and less side wash would result against the banks.

In conclusion I give a few extracts from the *Minneapolis Evening Journal,* from an article in regard to the canal agitation now in process in Washington. It bears date of Washington, April 20, 1900, and is written by W. W. Jermane. His arguments in favor of the Panama route are what I will quote, and they apply with equal or greater force to the San Blas route:

"The advantages of the Panama route are:

1. "The shorter length, a most important consideration. The proposed Panama canal is 47 miles from sea to sea, while the Nicaragua is 189 miles long." (The San Blas route is 29.17 miles long.)

2. "The existence of a railway parallel to the canal and considerable progress upon the work, each of which factors would secure the early completion of the canal." (A railway sufficient for construction purposes is easily built along the San Blas route.)

3. "It is claimed there is less danger of earthquake disturbances on the Panama route, and there exist more careful data as to rainfall and in the way of borings and necessary information as to geological formation." (The San Blas route is so near to Panama route that the same reasons will probably apply largely at the former location.)

4. "The possibility that improvements in engineering and excavation may ultimately give us a sea level canal." (On the San Blas route nothing but a sea level canal is proposed.)

5. "Much better harbors at two ends." (Equally true on San Blas route, where said harbors already exist, and a line between them "straight as a crow flies" is proposed.)

"Any person who carefully considers the situation must realize that there is enough of question between the two routes" (and also the San Blas route) "to justify careful examination and brief delay. The commission of engineers appointed by the President to examine it will be ready to report in a few months. Should their recommendations be unanimous it would be useless for the advocates of either" (or any) "route to contest the validity of their decision. The commission is made up of men of character and ability."

With this quotation I end this paper, and desire to say, without ostentation, that I believe the reasons I have presented in favor of the San Blas route are cogent and worthy of careful consideration.

DISCUSSION.

MR. JOHN C. TRAUTWINE, JR.—I venture to append, as a discussion of Mr. Redfield's paper, an abstract of a letter by my father, Mr. John C. Trautwine, Sr., to the *Polytechnic Review*, August, 1876, in which he gives decided preference to the San Blas route over all others, notwithstanding that he estimates its cost at more than three times that given by Mr. Redfield:

"Let us look first at the San Blas route. It crosses the isthmus at its very narrowest part, about 50 miles further down the coast than the Panama Railroad. For a tolerably correct idea of its general features I refer you to my map of the isthmus in the *Journal of the Franklin Institute*, January, 1871. The canal, starting at the Gulf of San Blas, on the Atlantic, would run nearly south to the mouth of the river Bayano or Chepo, on the Pacific. Two surveys have been made; one by the United States Government, and one by a party employed by Frederick M. Kelly, Esq., of New York, the Lesseps of the isthmus canal. Although neither of these surveys is by any means final, still they appear to warrant us in making the following assumptions,—namely, that the entire length of the canal need not *exceed* 35 miles, nor the length of its tunnel be *more* than 10 miles. I also assume that a canal intended emphatically for a '*world's highway*' should not, where in earth excavation, have a less width at bottom than 100 feet, with full 200 feet width at the water line and 30 feet depth of water; and that its side slopes should not be steeper than two horizontal to one vertical. For the tunnel, assuming (as appearances indicate) that it will all be in rock, I take its width to be 100 feet to a height of 40 feet above water surface, thence diminishing to the top by a semi-ellipse. Extreme height 200 feet, or 170 feet above its top water line. I also assume that all the excavation except the tunnel will be in earth. This will certainly not be the case; but where it is in rock

the slopes of the cuts will be made steeper, thus reducing the *number* of cubic yards in about the same proportion that the *cost per yard* would be increased, so that the entire expense will be about the same in either case.

"On the foregoing maximum assumptions, aided by the best judgment I can form from the published reports and profile, I conceive that the total cost of the San Blas route *cannot exceed* the following:

Ten miles of tunnel; 35,000,000 of cubic yards of rock at $5......	$175,000,000
(This price includes the depositing of a comparatively small portion of the rock to form a complete riprap facing for the protection of all the earth slopes of the canal cuttings.)	
Earth excavation and dredging; 100,000,000 cubic yards at 75 cents	75,000,000
(This price includes all clearing away of trees, and other incidentals, as dredges, etc., etc.)	
Two tidelocks and their accessories........	5,000,000
	$255,000,000
Contingencies, 15 per cent........	38,250,000
(Including harbor improvements, forts, lighthouses, commissary and medical departments, roads, dwellings, stores, police, telegraphs, engineering, superintendence, etc., etc.)	
Total	$293,250,000

Or, say, in round numbers, $300,000,000 (without including interest during construction), or about three times the cost of the Suez canal.

"It is not impossible, but, on the contrary, quite probable, that a more detailed survey of the San Blas route may result in so improving it as to enable us to reduce this estimate to $275,000,000, or even less. As to any reduction by diminishing the cross-section of the canal or of the tunnel, I can only say that I should consider it entirely inexpedient in a '*world's highway*.' Respecting the prices assumed per cubic yard, I do not regard them as more than sufficient, in view of the peculiarities of the climate, especially with respect to rain and health. Moreover the contingent expenses of the contractors in the construction of their buildings, making roads, clearing of forests, etc., will be very heavy; and during the rainy season all kinds of work will be carried on under great disadvantages, such as cannot be realized by any one who has not experienced them.

"Again, a route has been suggested to run nearly side by side with the Panama Railroad. This would have very important advantages over any other, in the facilities for the transportation of

men, materials and supplies; but my experience as chief engineer of that railroad during 1850 enabled me to see that that route, with tide locks only, would for ten or twelve miles involve a tunnel and deep cuttings fully as expensive as those on the San Blas line, while for the remainder (about 40 miles) of its length the cost would be considerably greater than on the San Blas, the same dimensions of canal and costs per cubic yard being of course adopted in estimating each."

In the *Engineering and Mining Journal* of July 5, 1879, my father is quoted as saying that the Panama route "is perhaps the least eligible of all the proposed Darien routes"; that the numerous locks of the Nicaragua route "should exclude it from consideration," and that, "taking into consideration the loss of interest on money and the cost of damages from floods, it is very doubtful whether $500,000,000 and twenty-five years of time would suffice to construct the Panama canal; or whether it would ever pay if built, as he feels confident it never will be." He regarded the liability to earthquake disturbances as a serious consideration, common, however, to all the routes.


MAP OF THE
ISTHMUS OF SAN BLAS.
SHOWING
AIR LINE ROUTE FOR SHIP CANAL.
SCALE: 1 : 200.000.
STATUTE MILES
NAUTICAL MILES
KILOMETRES
BAY OF PANAMA.
Chepillo Island.
GOOD HARBOR
BAYANO RIVER
LINE OF SHIP CANAL
SECTION 1, 10.101 MILES
SECTION 2
8.996 MILES
TUNNEL
SECTION 3
7 MILES
SEC 4
3.073 MILES
Great Bend
Change Channel
Head of Tide.
Mamonin Riv.
Sello Falls
CORDILLERAS OF CHEPO
CORDILLERAS OF SAN BLAS
Mandinga Riv.
Carti
River
Plantation
Carti Village.
GOOD HARBOR
Porter Channel
GULF OF SAN BLAS.
San Blas Channel
Chichime Ids.
Profile.
Vertical Scale 1 : 80,000.
CORDILLERAS 1142
Mouth of Bayano R.
Mouth of Mamonin R.
Head of Tide
Sello Falls 74
323
503
309
92
Mouth of Mandinga Riv.

Editors reprinting articles from this journal are requested to credit both the Journal and the Society before which such articles were read.

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SIPHONS.

By Thomas McKeown, Member, American Society of Civil Engineers.

[Read before the Engineers' Society of Western New York, May 7, 1900.*]

It is generally believed that the first siphon was made at the school of the Ptolemies at Alexandria, about the year B.C. 120. Archimedes of Syracuse, a pupil of the same school, 130 years earlier, gave to the world the fundamental hydrostatic law of equal pressures.

The Romans, in furnishing the necessary water supply for the city of Rome, seem to have confined themselves almost entirely to the use of open aqueducts, though they certainly understood the fact that water, conducted through closed pipes, would rise to the level of its source. It is highly probable that the great cost of lead, the only metal then made into pipes and strong enough to bear any great pressure, forced their engineers to the other absolutely certain method of open conduits.

A large district about the city of Aix, in France, is supplied with water for irrigation, and the city for domestic and manufacturing purposes, from the River Verdon, the water being conducted through inverted siphons across the valley of St. Paul. The siphons are two wrought iron tubes, each 69 inches in diameter.

The new source of the water supply for the city of Manchester, in England, is Lake Thirlmere, in Cumberland. The water will have to be conducted a distance of 96 miles. In this distance there are several inverted siphons. The longest is 3½ miles in length, formed of five lines of cast iron pipes, each 3½ feet in diameter; in

*Manuscript received June 7, 1900.—Secretary, Ass'n of Eng. Socs.

one case the pressure will be about 180 pounds per square inch. The hydraulic head is about 420 feet.

An American author, in his work on hydraulics, describes a siphon in Scotland 1400 feet long, made of half-inch pipe, and states that it continued to flow without ceasing for fourteen months, though nothing was done to guard against the accumulation of air at the high point of the siphon.

I presume the reason we have so little historical mention of the application of the siphon to actual work is that it is only during the last few years that iron pipes have been made cheaply enough and of sufficient size to justify their use in large engineering works; but, with increasing facilities for making wrought and cast iron pipes of almost any size, and the fact that engineers to-day are continually on the watch for every opportunity to apply well-understood principles to new and enlarged conditions, the siphon, which is capable of doing good and useful work, should have a chance to display its good qualities on a much larger scale than has heretofore been permitted. Many occasions are sure to occur where the conditions are suitable to the use of large siphons, and where a large financial saving may be effected by their use.

What I have already said naturally leads me to mention the siphon that my firm has proposed to the municipal authorities of our own city to use in transferring the sewage from the Hamburg Canal to the Niagara River, below Ferry street. This siphon would be a 4-foot cast iron pipe 15,000 feet long, and at its highest point 15 feet above the level of Lake Erie. The difference of elevation between the upper and lower ends of the siphon would be about 5 feet, and, allowing that the flow through the siphon would be the same as the flow through a closed pipe of the same diameter and having the same fall per unit of distance, the discharge would be at the rate of 30 cubic feet per second, which is a quantity greater than the present intake of sewage of the Hamburg Canal. The siphon would be provided with valves at both ends of the pipe, with proper appliances for opening and closing them, and with a valve at its highest point for charging it with water, and so arranged that a jet of water carrying a high pressure could be applied in the direction of the movement of the water so as to accelerate its flow through the pipe whenever desirable. It would also be provided with an air chamber, so that the accumulation of air could be noted and exhausted without interfering with the continuous flow of the siphon; and the idea in making this proposition to the city was that the conditions in Buffalo are especially favorable for operating a siphon to move the sewage from the Hamburg Canal to the Niagara

River below Ferry street. The object in constructing an air chamber at the high point is to take care of any air that may accumulate in the pipe. The pressure would be less at the high point, and the air would escape at this part of the siphon. If the chamber was built, the quantity of escaping air could be noted and immediately exhausted.

I see no reason why a siphon constructed on these principles would not work. Certainly, it is cheaper than constructing a sewer of the same size. I tried to make the city of Buffalo and our friend Mr. Bardol see the matter from our standpoint, but have not been able to do so. We have not lost all hope, though. I think the reason we have not had siphons of large size is that we have not had pipes of the material and size.

DISCUSSION.

Mr. Ricker.—The siphon will not work unless it is full, will it?

Mr. McKeown.—No; it must be running full. Unless it is, it will not work satisfactorily.

Major Symons.—Are pumps to be located at the summit in your plan?

Mr. McKeown.—No; there will be an air chamber at the summit with a system of valves that could be opened or shut, so that this chamber could be separated entirely from the rest of the siphon.

Mr. Knapp.—What is the velocity per second?

Mr. McKeown.—I calculated that the flow through a pipe of this diameter would be about $2\frac{1}{2}$ cubic feet per second, exactly 2.36 feet per second.

Mr. Guthrie.—Suppose the siphon will flow. It seems to me that in a pipe of that length and diameter, with a fall of 5 feet, the velocity will be less than 2.36 cubic feet per second.

Mr. McKeown.—We made some experiments with siphons as compared with a straight pipe, and concluded the flow would be the same.

Mr. Knighton.—Would there be any necessity for filling this pipe to put it in operation?

Mr. McKeown.—No; a pump could be operated at the highest point, and as the air was exhausted the water would rise in the pipe until the pipe was full. Then, the valves at the ends being opened, the difference of hydrostatic pressure would act as the lever of an engine, throw the machine off the center and it would begin to move. We considered the filling with water the better method.

Both ends would be closed, and it would simply be necessary to open the valves simultaneously.

Mr. Knighton.—What is the highest elevation?

Mr. McKeown.—Fifteen feet.

Mr. Knighton.—What is the size of the pipe?

Mr. McKeown.—Four feet. The only question is one of size.

Major Symons.—Have you constructed a model? You say it is simply a question of size.

Mr. McKeown.—It would be difficult to construct a model that would give correct comparative results, because by contracting the diameter of the pipe we greatly increase the friction.

Mr. Guthrie.—Kansas City went to a great expense to put down a number of feet of pipe, and has had to take it up and go over all the joints looking for leaks. At Auburn, N. Y., they have a 24-inch siphon which did not work.

Mr. Tutton.—Is not that an inverted siphon?

Mr. Guthrie.—No, sir; that is a very different thing, simply a pressure siphon. In Virginia they had one for carrying sewage. I think it was about 1400 feet long. It was put down by the late Colonel Waring, where they encountered some rock, and it did not work long.

Mr. McKeown.—Certainly the pipe should be water-tight in order to work.

Mr. Guthrie.—There would be a tendency for air to get in the pipe and collect at the high point; and the farther you go from the summit, the less would be the flow. Air certainly would get in the pipe from time to time, and this would interfere with the working of the siphon. I do not see how that can be overcome.

Mr. McKeown.—If there were any air in the siphon it would be at the summit, and the valve chamber would take care of this. If there is any difference between the flow of a siphon or through a pipe I cannot find it. We tried to make some experiments, and, so far as they went, they seemed to indicate no material difference between the flow of water through a pipe and through a siphon.

Major Symons.—There is a siphon near Mt. Vernon 1000 feet long and 12 inches in diameter, with a head of 23 feet, to supply the water works. It ran all right for about four months, and then ran dry.

Mr. Guthrie.—That is a very high level.

Mr. McKeown.—It is not absolutely necessary that the level should be as high in this case.

Mr. Morse.—The pipe could be lowered.

Mr. McKeown.—Yes, sir. I think the difference in height between 15 and 34 feet would give us all the pressure we need.

Mr. Bardol.—In looking at any machine there are three things to consider: First, whether it will work at all; second, whether it will accomplish what is intended, and, third, its economy.

As to the first, whether it will work at all, I am open to conviction. With a pipe three miles in length and 4 feet in diameter placed on the ground it would be difficult to find a leak in it at any place. Of course, it could be caulked thoroughly, but if a leak occurred it might be at any point in the pipe.

One of the things considered in abating the Hamburg Canal nuisance was the lowering of the drainage area; this could not be accomplished with the siphon. Sooner or later the property in the vicinity of Exchange, Seneca and Swan streets, in fact all of the territory south of the canal, will have to have deeper drainage.

Another feature to be considered in connection with this siphon is the necessity of being compelled sooner or later to take care of all the sewage from the greater part of South Buffalo, beyond the river, and with a siphon we could not accomplish this.

The objection Mr. McKeown has to a pumping plant is that the Swan street sewer is now taxed beyond its capacity. That statement is not quite up to the facts, for the reason that the trunk sewer will take 20 feet per second more. Of course in time of storm there will have to be an overflow into the sewer in the canal.

As to the question of cost, the figures Mr. McKeown gave me were something like 15,000 feet at $15 per hundred, valves and valve house $15,000, making $240,000 for the cost of the siphon.

The cost of the pumping plant would be about $50,000, although the cost of operating the plant would be more than that of the siphon. I estimate the cost of operating the pumping plant at something like $7500 per year, and the cost of operating the siphon at $2500. Taking these figures as an estimate, there is a difference of $5000 in favor of the siphon. This, capitalized at 3½ per cent., equals $130,000. Taking the cost of the siphon at $240,000, and $50,000 the cost of the plant, there will be a difference in cost of $190,000 in favor of the plant. The report of the board winds up with the statement that the siphon, from any point of view, could not be recognized in any way. I do not know of any reason why I should change my mind. Mr. McKeown has not convinced me that his plan is feasible.

Mr. McKeown.—One of the things to be considered in connection with Mr. Bardol's plan is that in time of rainstorm the

Swan street sewer is more than full, and a large amount of this sewage would have to be dumped into the canal.

Mr. Bardol.—I think you do not understand the conditions. The siphon will take 30 feet per second in addition to what the Swan street sewer will carry. When you take into consideration that the amount of the diluted sewage in time of storm is 1300 cubic feet per second, the effect of diverting 30 cubic feet per second does not amount to much.

Mr. Haven.—When the city of Buffalo and Western New York is drained as it should be there will be no necessity for a siphon or sewer to Niagara River.

It was moved and seconded that a vote of thanks of the Society be extended to Mr. McKeown for his able address on the subject of Siphons. Carried unanimously.

TRUSTS AND THEIR RELATION TO THE ENGINEER.

By Charles H. Wright, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, May 8, 1900.*]

Since the issues of the days before the war, no subject has so stirred the American people as has the question of the trusts. From the center to the circumference, through all classes and conditions of the people, there are spreading waves of doubt, dissatisfaction and unrest.

No class is more deeply interested than the engineers. The relations of the engineer to the trusts are closer than at first appear; closer even than most of us realize. It is well, then, that we try to read the future, if we may, far enough to discover whither we are drifting, and how our prospects and our future are to be affected if the trusts shall continue. And is there any thinking man who believes for an instant that they will not continue, and that they will not increase?

We may hate and fear them, and try to convince ourselves that they are only temporary, but we know all the time that we are simply fooling ourselves.

The modern trust is a product of the times, a product of the circumstances and conditions which now exist.

To check the growth of the natural and lawful trust is to turn back the wheels of progress. To check these trusts is to accomplish the impossible.

What is a trust? I might almost say, What is not a trust? Where shall we draw the line?

Webster gives, among the definitions of trust, this: "Credit given without examination." While not so intended, it is certainly a terse and accurate definition of many of the mushroom enterprises which have sprung up in this country in the last few years.

Every person's definition of the term is colored by his temperament, his politics and his self-interest. Some look through the small end of the telescope, and some through the large end.

A fair definition of the term, as commonly accepted, might be: "The combination among a number of persons of their financial, mental or physical powers for the purpose of advancing their individual interests or for maintaining some advantage or superiority which they may already possess."

If we accept this definition, then, the uniting of the newsboys in your public squares to prevent other boys from selling papers

*Manuscript received May 11, 1900.—Secretary, Ass'n of Eng. Socs.

there is as truly a trust as is the "whiskey ring" or the Standard Oil Company.

The leaders of the labor unions are avowedly opposed to trusts, and yet they are trying to form and perpetuate one of the most merciless, vicious, brutal and irresponsible trusts the world has seen.

No combination of capital ever went to the extremes the labor unions have reached when the power has been in their hands.

The heads of the huge financial combines realize that their own interest demands that they give some little heed to the rights and interests of others.

The labor agitator knows no right outside himself. If he will not work,—and usually he will not,—then no one shall.

Eight hundred employes of a Lowell, Mass., carpet mill recently struck at the command of the leader of their union, because one woman insisted that she had the right to feel some little interest in her work. She had turned out more than the allotted work in the time. She had refused to remain idle when her "stent" was finished. She had actually gone early to the mill and cleaned and greased her loom, so as to be ready to begin weaving at the sound of the whistle. Thus she had not only violated the union rule, but had been reprehensibly industrious, and thus discredited her less ambitious associates. The President of the union remonstrated with her, and pointed out the wrongfulness of such industrious habits. She persisted in her right to work instead of loafing, and to earn all she could in the hours of work. A committee of the union went to the manager and demanded her discharge. The manager refused. Then she was expelled from the union, the three hundred weaving girls struck, the mills were necessarily closed and eight hundred employes were reduced to idleness.

Human nature as a whole is pretty much the same in the Wall street office as in the mill and factory. While human nature is as it is, and while self-interest remains the controlling factor, so long will the trust and the labor union remain. It is right that they should remain.

They have both to learn, by bitter experience perhaps, that in the exercise of their own rights they must not lose sight of the fact that others have equal rights.

I have faith to believe that the American people will find a way to settle the question of both, with justice and fairness to all, as they have settled other questions. When the time comes it may be that the engineer will be an important factor in the settlement.

Contrary to popular belief, the trust is not of recent origin. It is as old as the ages, as old as history itself.

In this country there are enormous combinations of the transportation companies, huge combines so vast and so far-reaching in their interests that the mind almost fails to grasp them.

The Morgan syndicate owns or controls all the railroads leading east out of Chicago with the one exception of the Pennsylvania Company, and the relations of this road to the combination are doubtful. Practically every steam road in New England is in the combine.

There are over forty thousand miles of road included in this trust, and the employes number over three hundred thousand; yet huge as is this trust, it does not hold such an absolute and perfect monopoly of the transportation business as did Noah and his ark.

If history be true, there were people even then who looked upon the trust with terror and dismay. Side by side, hand in glove, with this first great trust were the engineer and architect. They made its success possible. Without them there could have been no ark.

When we consider the huge cargo carried by this boat, and the lively and unstable character of its cargo, we cannot but feel admiration for the engineer who built the boat. The facilities and materials of construction were not as good then as now.

However the other branches of labor may be affected by the trusts, the engineer finds in them his opportunity. As a matter of fact, labor as a whole is benefited by them. I presume many of you will doubt this, but this table might be loaded with statements in proof of it. When the trusts are formed men are discharged; there is no doubt of this fact. It is said there have been 35,000 traveling men dismissed. No doubt this is true, but is it true that these men have been forced to remain in idleness? When the railroads were first started in New England there was a great cry about the poor stage drivers who would be thrown out of employment. For every one of these men who lost his work there were a hundred who found employment when the roads were built.

As you know, there has recently been formed a combine of the bridge builders. At first glance it looks as if this trust must have a disastrous effect upon many engineers. As we look more closely the county commissioner appears to be about the only one hurt, and perhaps engineers will not feel called upon to worry about the county commissioner.

Those of you who are bridge engineers do not need to be told that a very great saving can be brought about in the management of the bridge companies by the consolidation of the competing plants. Where perhaps twenty designs and estimates were made

for the same work under the separate management, only one or two are necessary when the different plants are united.

This seems to point to a reduction in the number of engineers employed. So far as the bridge companies are concerned, this is probably the case. There is another side, however.

The cream of the structural work comes from the railroads. At present, by simply asking for bids on certain work the railroads get the benefit of the knowledge and experience of the engineers of the several bridge companies asked to bid. It cannot be expected that the same number of designs will be submitted by the trust. On the other hand, the railroad engineers will hardly accept without question whatever may be offered by the trust. A certain amount of preliminary designing must be done.

If the trust decides that it will no longer maintain a free engineering bureau, the railroads will be compelled to do this work themselves. Many of them are already doing it. If they take the wiser course and turn this work over to the engineering firms who make a specialty of this work, a long step will have been taken in the direction of economy, good design and sound common sense.

The men who have gained knowledge and experience by years spent in the offices of the bridge companies will find plenty of opportunities, either with the railroads or in the office of the expert.

Incidentally, it might be remarked that the bridge trust itself has not a pathway strewn with flowers ahead of it. As stated above, the most desirable work comes from the railroads. Does any one imagine that the railroads will allow the bridge trust to dictate prices to them? When prices reach a certain point the railroads will build their own bridges. Some of the larger companies are in a position to do this at any time.

It will be interesting to watch developments in the bridge trust for the next year or two.

The American Steel and Wire trust for a little time has bid fair to rule a certain line of manufacture. Now the construction of new and independent mills is probably a certainty, and it is not probable that the new plants can ever be controlled by the wire trust.

This means very much to the engineers. The new plants must be the most perfect that ever have been erected. The ability and the genius of the inventive engineer will be taxed to the utmost. Consider for a moment how far-reaching this single new interest will be in its effects. Engineers in every branch will find opportunities here. If the new supply exceeds the demand, it simply means that new uses will be found for these materials; there is a vast field yet open in this direction.

At one time the ore and coal shipped from the great lake ports was handled by laborers; then came the machines for handling these materials, and the laborers lost their employment. The increased economy in handling, combined with other causes, increased the production of iron and steel, and many more men were soon required than had been replaced by the machines. Perhaps the new requirements were for a higher grade of labor, but there is no law against the laborer fitting himself to do a higher class of work. The country is full of opportunities for men to obtain an education and a training for better things. When the dock laborers were replaced by the machines, skilled machinists, draftsmen and engineers were required to build the machines. New boats and new lines of railroads were built to transport the raw materials and the finished products.

New furnaces and new mills were built. New machines and new devices for the economic handling of material at the mills and furnaces were required, and an endless line of improvements followed all through the iron and steel industries and the allied lines of manufacturing.

All this gave employment to the engineer.

No truth seems harder for the American people to understand, and yet no truth is susceptible of more perfect demonstration than is the fact that any advance in the industrial world which cheapens the cost of production or increases the possible output is in the end a direct benefit to all classes.

The world always has been, and always will be, a hard one for the aged and the incompetent. We all realize and regret this, but is it advisable to limit the speed of all to the capacity of the most feeble?

"Through the ages one increasing purpose runs,
And the thoughts of men are widened by the process of the suns."

Much of the complaint about the trusts would cease if men would recognize that changes must come in methods and means, and that they must fit themselves to become valuable elements in the readjustment.

You hear on all sides complaint that the trusts and large employers strive to specialize and limit the lines of individual labor. There is complaint that there is no longer opportunity for men to become proficient in several branches, to become good all-around men. This claim is utterly without foundation in fact. Never have the opportunities been greater. The desire, however, seems lacking.

Watch the construction of some large building. One man must lay the bricks; another must plaster the walls. The man who puts up the steel frame must not put in the wooden floors. If the plumber wants a bracket here and there the carpenter must be called, but he must not put in the broken pane of glass; the glazier must do this. If the carpenter takes off a few slate on the roof he must not put them back; the roofer must be recalled, and so on all through the construction. If the aim of the laboring men is to see how useless, valueless and helpless they can make themselves, they must be succeeding beyond their fondest hopes. These one-idea men are most loud in their complaint that the employer takes them at their word, and treats them accordingly.

Again, we hear of men being forced out of business, compelled to sell out or join a combine. No doubt many have been compelled to do this. On the other hand, many men who have been struggling along for years, barely keeping their heads above water, have found in the trust a market for an old, run-down and out of date plant at a value much beyond its actual worth.

What becomes of these men, the former owners of these plants?

Suppose one hundred men enter a combine, and only ten of them are then required to manage the business. What will the other ninety do? Many of them are perhaps as bright and capable as the heads of the trust themseles. Will these men sit down, fold their hands and call their lifework done? I hardly think so if they are Americans.

Have we reached the limit of production? Have we reached the point where there is nothing more that can appeal to the wants, the convenience or the luxurious comfort of the people? Is there nothing more to be invented? Have we seen the end of all advance? No. There is plenty yet to do, and no need that any man or class of men remain idle.

That the trusts need to be firmly and steadily controlled we will all admit. The question is, How shall this be done? During the Chicago conference Mr. Bryan was asked to give some method by which the trusts might be controlled.

It is surprising how early associations and influences make themselves felt in later years. Mr. Bryan spent years of his life on the prairies of the West. From his memories of boyhood days on the farm came his inspiration. He had seen droves of hogs wandering in the tall grass, and rooting up with equal disregard the property of their owner and his neighbors. "My friends," he said, "we will treat the trusts as we treat the four-legged hogs of the prairies, we will put rings in their noses."

Well, if a ring is to be put in the nose of the trusts, who is to do it? I imagine it will be an engineering problem and that the engineers will have to do it.

A well-known engineer recently tried to prove that the reason there were more and better engineers to-day than twenty years ago was because the engineering schools were turning out a better grade of engineers.

If you place fifty trained and skilled physicians in a small country village few of them will, if they remain there, ever acquire any great wealth or fame. The opportunity is not there, and, no matter how great the physician's skill, he will find no occasion to exercise it.

It is so with the engineer. While it is true, to a certain extent, that the engineer creates his opportunities, he will not make a much better showing than the physician unless he have the help that great wealth alone can give. The engineer, more than any other professional man, requires the backing of capital. The trust is in the position to give this all-important aid.

We hear a great deal about the trusts increasing the prices of the materials controlled by them. Up to a certain point they can do this; beyond that point they cannot do it. You can rest assured that when they are putting the price above what is included in manufacture and a fair profit, they are paying some one else more to keep out of the business than they are making themselves. Any article that one trust can make, another can and will when there is a profit in doing so.

Is it sound business policy to keep prices above a reasonable point? Which is the successful merchant, the one who handles many goods at small profit or the one who sells a small amount at a very large profit?

The people fear the trusts because they do not understand them, and do not know that 75 per cent. of the so-called trusts will be blown to the four winds of heaven when the first breath of business depression strikes them. Imaginary profits on imaginary capital are about as satisfying as bread made from sawdust.

I may own a dog worth two dollars, and may form a company and sell a thousand shares of that dog at ten dollars each (if I can get any one to buy them), but I have not created any wealth. I have simply transferred wealth from the pocket of some one else to my own pocket. Everything looks all right perhaps, and there is no trouble until I have to pay dividends on the shares of that dog. When that time comes, then trouble begins.

In considering trusts and their relation to the engineer, I have had in mind only such trusts as had some good business ground as a basis for their existence. It is true, however, that many of the bogus trusts have very materially benefited the engineer. This is the least attractive side of the subject, however. Engineers did not feel great pride in the work done by them on the wild, visionary and bankrupt schemes which marred the landscape at the Chicago Fair, for example.

It is interesting to follow briefly the history of the trusts. Prior to the war they were not very plentiful. The air was full of the symptoms, however, and all that was needed was the proper conditions to bring out the fever in all its violence. In the sixties the father of all modern trusts, the Standard Oil Company, came to life, and paved the way for all the rest. Then the panics, failures and general demoralization which took possession of the business world from 1873 to 1877 brought out the trusts in flocks. Business men banded together for self-protection.

Then the people became alarmed, and the State Legislatures and Congress passed all sorts and conditions of anti-trust laws. Little else seems to have been considered by these bodies between 1887 and 1893. The people sent lawyers to make laws against the trusts, and the trusts employed these same lawyers, at enormous salaries, to tell them how to avoid the laws they had made and render them of no effect. If the trusts were driven from one State, they applied for a charter in another. This charter gave them power to do business in any State. If forced to disband, they formed social clubs (presumably to discuss politics). These clubs became the business offices of many of the trusts.

During the year 1899 347 industrial corporations were organized, with a total capitalization of $3,593,530,000. The list that follows has been compiled by the *Railroad Gazette* from the *Commercial and Financial Chronicle*. A large proportion of these corporations are simply combinations or trusts, designed to obtain the economies of consolidation and the security of partial monopoly. Notable examples are the American Car and Foundry Company, $60,000,000, which owns, with few exceptions, the important car-building plants; the American Bridge Company, $67,500,000, which proposes to control the great competing bridge works. The twenty-three iron and steel companies, with an average capitalization of $19,000,000 each, are all combinations. In all of these cases the proportion of money finally withdrawn from other uses and invested in industrials is small. The combining manufacturers receive payment for their plants either wholly or in part in certifi-

cates of stock and cash. The cash is obtained by selling to the public—the innocent, unsuspecting public—a small part of the stock. There are, however, many entirely new industries inviting new capital to exploit new propositions. To build and sell automobiles twenty-four companies have been organized, with an average capital of $10,000,000 each. To handle liquid air three companies invite investment in $25,000,000 of capital stock. To promote a locomotive smoke preventer $6,000,000 is considered desirable. The following incorporations of 1899 are especially interesting:

American Bridge	$67,500,000
American Car and Foundry	60,000,000
Columbian Electric Car Lighting and Brake	10,000,000
Doty Third Rail Electric	2,500,000
Electric Axle Light and Power	2,500,000
International Car Wheel	15,000,000
International Steam Pump	27,500,000
Locomotive Smoke Preventer	6,000,000
Magnus Metal	3,000,000
Murphy Safety Third Rail Electric	2,500,000
National Tube	80,000,000
Niles-Bement-Pond	8,000,000
Pressed Steel Car	25,000,000
Southern Car and Foundry	3,500,000
Strohm Automatic Electric Safety Block System	5,000,000
U. S. Cast-Iron Pipe and Foundry	30,000,000

The year 1900 will probably show a much greater record. Among the large companies already incorporated this year are the American Steel Sheet Company, with a capital stock of $52,000,000, and the Carnegie Company.

The Carnegie Company was incorporated at Trenton, N. J., March 24, with a capital stock of $160,000,000, divided into shares of a par value of $1000 each. The State of New Jersey receives a $32,000 fee for the incorporation and an annual franchise tax of $11,750.

This new company acquires the interests of the Carnegie Steel Company and its subsidiary companies and connected interests at a valuation of $250,000,000, payable one-half in stock and one-half in 5 per cent. gold bonds; and the H. C. Frick Coke Company at a valuation of $70,000,000, similarly payable half in stock and half in bonds. In other words, the various interests of the Carnegie and Frick Companies are taken over by the New Jersey corporation at a total outlay of $160,000,000 in stock and $160,000,000 in bonds, $320,000,000 total. All these companies, however, maintain their identity under their several charters, the Carnegie Steel Company,

under a new Pennsylvania charter, with a capital of $50,000,000, succeeding to the Carnegie Steel Company, Limited, whose articles of association as a limited enterprise would have expired April 1, 1901.

While the trusts are increasing, and while laws are being made to abolish them, and while public honesty and morality are slowly being taught, let the engineer make the most of this, his golden opportunity.

Without the union of the railroad interests the numerous terminal stations of the great cities would never have been built. The same is true of many other railroad improvements. All the great combines have called upon the engineer to carry on works which never would have been constructed by individual enterprise. Small independent industries have not the means to spend in experiments and the trial of new inventions. Combinations of capital stand ready to do this if they see profit to themselves at the end.

Every new invention opens the way for others, many of which require large capital to put them in operation.

One might go on indefinitely citing instances where the engineer finds the door to employment, and possibly to fame, opened to him by the hand of the trusts.

Without the engineer the trust is helpless. Without the trust the engineer never would see the successful completion of the grandest products of his genius.

THE USE OF ACETYLENE IN RAILWAY STATION AND TRAIN LIGHTING.

By A. Lipschutz.

[Read before the Civil Engineers' Society of St. Paul, March 5, 1900.*]

The question of lighting isolated plants has, until lately, been one of the most difficult to deal with, on account of the inadaptability of the several sources of lights for this purpose. It is conceded that lighting with oil or kerosene lamps is insufficient in brilliancy and obnoxious on account of the smell, and therefore, in all cases where gas from a central station at a reasonable price was not to be had, the choice of lighting has generally been a system of arc lights or incandescent lights, or a mixture of both. A great many railway stations require less than fifty lights. In order to provide for that number of lights the cost of an electric light plant would be excessive, always taking into consideration that no direct connection with an existing system of electric lighting can be made. Even when renting electric light from a corporation or a private individual, the cost, as a rule, has been high enough to make it preferable to endure the inconveniences and semi-darkness of kerosene lamps instead.

In the last few years, however, a new light, which seems to be admirably adapted for the purpose of lighting isolated plants, has made its way slowly and steadily to the front. This new source of lighting is the much-slandered king of all illuminants,—namely, acetylene. The great ease with which this gas can be manufactured and the small cost at which it can be installed have emboldened many to place on the market apparatus which has been the means of delaying the ultimate success which this gas, in spite of all objections, is bound to gain for itself.

Given a piece of carbide, two tin cans and some water in which to throw the carbide, and you will have gas as pure as it is made with most of the modern apparatus.

The composition and properties of acetylene have been little understood, even by those who made it a business to build apparatus for its generation.

To the engineer who wishes to familiarize himself with the practical and salient points of this gas, its adaptability for certain service, its danger, etc., time is generally not given to take up a lengthy study in order to make himself acquainted with its chemical and physical properties. With this fact in view, some of the most

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important properties of acetylene will be mentioned. The greater part of the information to be given has been taken from the admirable lecture of Professor Lewes, the famous expert, whose lectures were published in full in the *Progressive Age*.

Acetylene gas has been known since 1836, when Mr. Edmund Davy produced this gas and called it bicarbonate of hydrogen. He was the first to make public its splendid qualities as an artificial illuminant, and predicted that it would take the lead of all if it could be produced cheaply enough. As the carbide which he used for generating this gas was a combination of rather expensive materials, it is easily understood that from that time on little had been done or heard regarding acetylene as a lighting medium, and it is due to the invention of Mr. Wilson, who in 1892 found a commercially successful product in calcium carbide, that this gas could be produced at such a price as to enable it to enter in competition with other sources of lighting.

Calcium carbide is now made by fusing 100 parts of lime and 70 parts of coke in an electric furnace. The material used for the manufacture of carbide must be of great purity; the lime should contain, on an average, 99 per cent. of CaO, and the coke should not run over 5 per cent. of ashes. The lime and the coke are crushed to nut size, then ground to powder in mills, and finally screened. The materials are then weighed and mixed; the latter process is continued for at least five minutes for the sake of uniformity. The mixture is then introduced into the electric furnace and fused under the electric arc. When cold and broken into pieces, carbide has the appearance of granite, and is equal to it in hardness. A temperature of 2700° C. is required for its formation. As carbide absorbs moisture from the air very greedily, it must be protected, in transit as well as in storage, from the influence of the atmosphere. It is therefore shipped in air-tight packages, and, when kept above ground in a dry place, there is absolutely no danger connected with its storage.

Carbide, manufactured as above, is an almost pure product. For manufacturing purposes, one mechanical horse power is required for a yearly output of 1.1 tons of carbide.

Carbide is sold at present, in carload lots, at $68 per ton, with strong indications of a reduction in this price as soon as rival capital shall compete in this field.

The most objectionable impurity in carbide is magnesium, which, while melting, takes up nitrogen from the air and forms magnesium nitrate. Such carbide, when in contact with water, gives out a gas rich in ammonia, which, if not washed out of the gas, will clog up gas pipes and burners and produce smoking.

Berthelot first made definitely known the true composition of acetylene as 92.3 carbon and 7.7 hydrogen, with a density of 0.92. If carbide is placed in contact with a small quantity of water it will not generate pure acetylene gas, as the heat developed by its generation will allow the acetylene to polymerize, and the result will be a gas rich in benzine, naphthaline and other polymers, which lower the candle power of the gas and cause it to vary with each instant, as the lighting, under such circumstances, is done with benzine vapor instead of acetylene gas.

Acetylene is colorless, and when pure and dry it has a special, not entirely disagreeable, smell, as it is neither acrid nor corrosive; when hot and moist, however, the odor changes, as it contains then the products of polymerization.

The temperature of inflammation of acetylene is about 400° C., and its temperature of combustion about 2000° C. It therefore has nearly two and one-half times greater heat of combustion than illuminating gas per cubic foot, but for equal amounts of light it gives out very much less heat than illuminating gas. It needs twelve and one-half volumes of air for its complete combustion. The fear of acetylene as a poisonous gas was dispelled several years ago, as it has been conclusively shown by very extensive experiments that its toxic qualities are less than those of coal gas. There has been a universal belief that this gas attacks metals, and especially copper, and forms with them explosible combinations; and even so learned a man as Professor Lewes mentioned in one of his lectures that, on account of this property, copper must not enter into the construction of an acetylene gas generator, only to declare a few months later, after hearing of the Pintsch Gas Company's experiments, that his position with regard to the use of copper and brass in connection with acetylene gas had been erroneous. In the summer of 1895 the Pintsch Gas Company made the following experiments, in order to throw light on this vexed question: They filled several steel tanks with acetylene at a pressure of 150 pounds per square inch, and placed in these tanks numerous articles made of nickel, brass and copper, and exposed these tanks on the roof of a building during nearly an entire year to the extreme heat of the summer and the severe cold of the winter. After opening these vessels it was found that none of the metals had been attacked by pure acetylene gas, and that even in some tanks where unpurified gas had been stored only oxidation had taken place. In no case was it possible, by either pressure, or hammering or heating, or a combination of these methods, to produce explosion.

Bullier, the French scientist, suspended copper plates, freed from surface oxidation, in acetylene for a period of one year, at the end of which time the copper was found to be as bright as the day it was put in. The valves of the acetylene apparatus in his laboratory, which were also made of copper, showed absolutely no sign of having been attacked by acetylene after two years' service. Since these experiments were made we have ourselves observed generators with copper parts and also brass pipes used in chandeliers, which, after more than two years of service, have shown no signs of being in the slightest affected by the gas.

Acetylene gas becomes liquid under about 700 pounds per square inch of pressure at ordinary temperature. At 37° C., which is the critical point for acetylene gas, it requires a pressure of 1000 pounds per square inch to liquefy it. When this temperature is passed no pressure will convert it into a liquid state.

Acetylene gas, when heated to 1432° F., will dissociate, and, when not compressed to more than 30 pounds per square inch, the dissociation is confined to the point where the heat is applied, and thus no explosion occurs. When, however, it is subjected to a pressure of more than 30 pounds and heated to the dissociating point, a violent explosion follows, resulting in the destruction of the confining receiver. Acetylene gas not compressed cannot be exploded by shock, heat or concussion. A pipe leading from a gasometer filled with acetylene gas was heated to a white heat about five feet from the gasometer, and, while local dissociation of the gas at the heated point took place, no explosion could be produced. The shock of a bullet shot through a tank filled with 150 pounds compressed acetylene gas also failed to produce an explosion. The crushing of a receiver, filled with acetylene gas compressed to 150 pounds, under a ram weighing 600 pounds and falling 20 feet, produced neither explosion nor ignition.

Acetylene, like every other combustible gas, forms, with air, an explosive mixture, and a room or building containing an acetylene gas generator must be well ventilated, in order to allow for a proper exit of gas leaking from the generator.

As already stated, acetylene has a great density, and a receiver, such as a gas bell, for instance, open on top, will retain gas several days if the gas is not blown out by a current of air. Hence no repairs, requiring soldering or heat, should be attempted at an acetylene gas generator until all traces of gas have been expelled from the apparatus.

Non-observance of the two rules just stated has been the cause of nearly all acetylene gas explosions in practice.

As the carbide commercially manufactured is never chemically pure, it introduces impurities in the gas, of which the principal ones are ammonia, phosphuretted hydrogen and sulphuretted hydrogen. It is due to the two last-mentioned impurities that acetylene gas has a disagreeable garlic-like smell, which disappears whenever these impurities are removed. With very few exceptions, chemical purification of acetylene gas has thus far not been resorted to in this country, for which the following reasons might be briefly stated:

The commercial carbide, as furnished to consumers in the United States, is of greater purity than the similar article in Europe. A second and probably more valid reason is that very few attempts have been made in this country to burn acetylene with mantles, as in incandescent gas lighting; in which case it has been found that the organic sulphur and phosphor compounds of the unpurified gas would break down the mantles, thus making a chemical purification of this gas compulsory. Besides washing the gas free of ammonia, which is now done in connection with nearly all modern generators, the elimination of other impurities might be accomplished by three different processes,—viz, (1) passing the gas through chromic acid, (2) the use of bleaching powders and (3) the application of acid copper salts.

A comparison of the different qualities of rays given out by the several light sources is stated as follows:

Coal gas gives out a weak light, with yellow rays; destroys colors, heats the air and has strong toxic qualities. It is weak in diffusive power.

Electric arc light has pale, sickly, violet rays, but is very intense. It is, however, the least diffusive of all lights, and is therefore rapidly being supplanted by other and more diffusive lights.

Incandescent electric light has reddish rays, mixed with yellow, and is fatiguing to the retina; but gives out little heat.

Incandescent gas light is too often rich in greenish rays.

Acetylene gives pure white rays; does not change colors; is least fatiguing to the retina; has but slight toxic qualities, and, being the most diffusive of all lights known, approaches most nearly sunlight. It has eleven times greater illuminating power than coal gas.

When carbide is placed in contact with water, gas is immediately generated.

The different ways in which these two substances may be brought together have given rise to an apparently countless number of generators, all of which, however, may be classified under three different methods of generating this gas,—namely:

1. Water drips or flows to the carbide.
2. Water rises to the carbide from below.
3. Carbide is dropped or thrown into a large body of water.

The generators of the first system are mostly used for small experimental and portable apparatus, such as headlights and bicycle lamps. The high temperature of generation incident to bringing a comparatively large quantity of carbide together with a small quantity of water results in the product of a heated, and therefore impure, gas, for which reason such apparatus is unsuitable for any large installation. In another construction of this type of generator water flows through a pipe onto the carbide, which is stored in a receptacle, which in its turn is connected with a gasometer. When gas is generated the bell in the gasometer rises, and when in its highest position closes a valve in the water pipe, thus stopping further generation of gas.

Still another form of generator has a closed carbide receptacle immersed in a tank of water, and a water-supply pipe leading from the carbide receptacle into the tank. Water pours in through this pipe and onto the carbide, until the pressure of the gas rises sufficiently to drive back or hold back the water in the supply pipe.

This type of generator has, besides the above-mentioned defects, the disadvantage that, in the absence of an especially large gasometer, the generation of gas, after the water supply is cut off, may raise the pressure in the pipes and generator to a dangerous degree.

In the generator mentioned, sticking of the water valve or failure of the levers or other means for opening this valve may also result in a dangerous rise of pressure.

Generators of the second system are constructed on the following principle: In a tank filled with water is inserted a bell, free to move up and down on guides. The carbide receptacle is hung inside of the bell, and when the bell is in its lowest position water flows through holes or sieves in the bottom of the carbide receiver. Gas is instantly generated, and its pressure raises the bell, and with it the carbide receiver, thus lifting the carbide supply away from the water and stopping further generation.

There are in use numerous modifications of this method, of which one may be mentioned in which the carbide remains stationary, while the water surface is acted upon by the gas pressure, alternately rising to and receding from the carbide, according to the demands of the machine.

This entire class of generators is open to the same objection as the class first considered. They also continued to generate gas when water is removed from the carbide.

The third class of generators operates by throwing or dropping a small charge of carbide into a closed tank filled with water. The gas thus generated bubbles through the water, and is led to a gasometer which is large enough to accommodate the amount of gas which the small charge produces.

The charge introduced in the generator falls on a grating, and, being surrounded by a large mass of water on all sides, generation takes place with but little rise in temperature. The gas, by rising in bubbles to the surface of the water, is washed, and contains only traces of ammonia.

With gas produced by this class of generators it is impossible to stop up pipes and burners, as the ammonia and other tar-forming ingredients have been washed out of the gas by its upward passage through the water. From such a generator, which has been in active use part of the day, evenings and nights for over two years, we have taken out pipes close to the generator, and also some near the burners, but all that could be found was some white spots like frost, due to lime being carried with the gas from the generator, and nearly all along the pipes the original scale of the iron was to be seen; and in the brass pipes of the chandeliers we could find no deposits or signs that the metal had been affected.

Such testimony has been corroborated by other disinterested parties in this country and Europe to such a degree as to make it advisable to consider for use in our plans only apparatus constructed on the third principle,—namely, that by which small charges of carbide are introduced by hand or automatically into a large body of water.

It is fully realized that a large amount of capital is invested in the manufacture of apparatus of the first and second systems, and the abandonment of these classes of generators will therefore be made unwillingly and slowly; but the future belongs, without doubt, solely to the generators of the third system.

As the charging and cleaning of generators are the only items of expense for labor connected with an acetylene gas installation, it becomes of importance that, with automatic machines, such as are used in smaller installations, a rather large machine be used. For instance, in a plant requiring fifty lights for three hours daily the consumption of gas would be approximately 90 cubic feet per day, necessitating a generator capable of holding 18 pounds of carbide. As there is generally, in a passenger station or freight depot, a man to be found whose duties will permit him to spend an hour in charging and cleaning the machine, it will be seen at once that a generator holding, for instance, 54 pounds of carbide would require

attention only about twice a week for a couple of hours, and such attention can be given without seriously interfering with the attendant's other duties.

The limit in size for an automatic machine is reached in a generator capable of holding a charge of 100 pounds of carbide. This would supply practically 150 lights for three hours. When an installation requires more than 200 lights it would appear best to use a machine charged by hand, and employ an attendant for the sole purpose of taking care of the plant.

This is by far the safest and most satisfactory way of generating, and there is no doubt that for all larger installations, and also for village and town plants, such a system, with a hand-fed generator in connection with a liberally proportioned gas-holder and a proper system of piping, will prove more economical and less liable to accidents than an installation with a number of automatic machines.

As before stated, there is at present in the market no generator which delivers a thoroughly dry gas, and it becomes therefore of the utmost importance, in piping for acetylene, to follow out the rule that all pipes must dip from the burner back to the generator, in order to free themselves from moisture and condensation, which otherwise will surely freeze up in the pipes and prevent the gas from reaching the burners.

It is self-evident that the generator room must be kept moderately warm all the year round, in order to prevent the water in the generator from freezing. There is no danger from the proximity of a stove or heater. The charging and cleaning of the generator is to be done by daylight, and no artificial light must be permitted in the generator room when the machine is open, as, for instance, in charging.

A burner consuming 1 foot of acetylene gas per hour will yield from 45 to 50 C.P. (candle power), whereby it will be understood that the piping for acetylene can be of much smaller size than for coal gas. It is, however, not advisable to use a smaller size than $\frac{3}{8}$-inch pipe. Common burner cocks, such as are used for ordinary illuminating gas, answer very well.

With reference to burners, it must be stated that good burners are still very expensive. Cheap burners are an everlasting source of trouble, and necessitate constant renewals. The only burner which has been found to work satisfactorily with acetylene gas is constructed on the following principle: The gas, before issuing from the burner, is divided into two tiny streams, so diverted as to form between them an angle of about 90°. These streams impinge

on each other, flatten out and form the flame, which is here not in direct contact with the burner, and thus an accumulation of carbon at the burner and a stopping up of the gas-hole is prevented.

All-lava burners are preferable to metallic burners with lava tips, although, if proper care is taken when applying the latter, good service can be had from them also. While we have burners under observation which, after two years' service, are still in good condition, it is not safe to figure the life of an average burner as more than one year. They should be tested before applying, for capacity as well as for efficiency, as it is not an uncommon occurrence to find in a gross of burners 10 per cent. unfit for use.

Before concluding this part of the paper, given over to a description of the use of acetylene for station lighting, it may be of interest to have some details of a plant in practice.

The Great Northern Railway has at Hamline a freight transfer house, which consists of a warehouse about 800 feet in length, having loading platforms at each side for the entire length of the building. The offices are located at one end of the structure. There are altogether about 100 burners, of which 26 are in the office, while the rest of them are grouped in three rows; one row being in the center of the freight house, and the other two rows on the platforms. The generator is installed in a small building about 20 feet distant, which also serves as a dinner room for the men. The office lights burn all night, while the lights in the freight house and platforms are needed for about four hours daily in the winter. The generator is a 100-pound carbide machine, and is charged every other day. The cost per lamp hour (22 C.P.) varies from 0.55 cent to 0.65 cent, according to the amount of gas used. This includes attendance, depreciation and renewals.

Formerly the lighting was done with kerosene lamps. Aside from the fact that it required the exclusive services of more than one man to fill, trim and clean 100 oil lamps daily, the light furnished by these lamps was found to be insufficient to do the required work. The light furnished by the acetylene plant has reduced the cost per ton of freight handled, and no other system of lighting could be installed at that place which would rival it in economy.

We have now a number of passenger stations and freight depots equipped with acetylene plants in operation, and several others under construction, ranging from 20 to 60 lights each, and in no case has an acetylene plant been decided upon except where, by its smaller operating cost, its independence of rented sources of light and its fine illuminating qualities, it has shown itself to be superior to other systems of lighting.

Acetylene in train lighting is by no means a newcomer. It has been in use for the last six years in England, Germany and France, in connection with several different systems.

The standard system of lighting trains of the Prussian State railroads, and also of some of the largest railroads of England and France, consists of carrying in gas tanks under coaches a mixture of Pintsch gas and acetylene compressed to 10 atmospheres, or about 150 pounds.

The experiments of the Pintsch Gas Company showed that the illuminating power of their gas was doubled when mixed with 20 per cent. of acetylene. The fact was also established that an explosion will not occur when a tank containing this mixture, compressed to 150 pounds, is heated to the dissociating point of pure acetylene.

Acetylene, when stored under a pressure of not more than 30 pounds, cannot produce a dangerous explosion when heated to the dissociating point, and the system of lighting suburban trains having short runs with pure acetylene carried in tanks under cars at 30 pounds pressure has been in successful operation for several years.

This system of low-pressure storage is, however, inadequate for long-distance trains, and in order to use acetylene stored at the same pressure as in the system of the Pintsch Gas Company, this latter company made tests with acetylene stored under 150 pounds pressure; first in a tank having riveted seams, and then in their own standard tank which has riveted and soft-soldered seams.

When the tank with riveted seams was heated to the dissociating point, or about 1432° F., an explosion took place which demolished the tank.

In the second test with their own tank, having soft-soldered seams, the solder commenced to melt when a temperature of about 380° F. was reached, thereby springing a leak by which the gas escaped, burning out quietly without any injury to the tank.

It was therefore concluded that acetylene under 150 pounds pressure stored in such a tank could be carried safely even in case of an accident by which the car might be overturned and the wreck catch fire. As already mentioned, there are no means of exploding a tank filled with acetylene gas at high pressure except by heating it to or above a temperature of 1432° F., as neither shock nor concussion will produce an explosion.

There appeared, however, another reason why the use of acetylene under higher pressure than 30 pounds was finally abandoned by the Pintsch Gas Company, and its system retained by which a mixture of Pintsch gas and 20 per cent. acetylene is used compressed to 150 pounds.

It is well known that from the gas tank under a coach a ½-inch pipe leads to the reducing valve, in which the gas pressure is reduced to about 2 inches of water. From the other side of the reducing valve starts the main car pipe by which the lamps in the car are fed.

This main gas pipe contains, therefore, gas under a pressure of only a fraction of a pound, and no heat applied to this pipe will cause an explosion. It is different, however, with the high-pressure pipe leading from the gas tank to the reducing valve. If this pipe were heated at a point about 4 feet away from the tank, and in such a way that the heat could not reach the tank and melt its seams, it was found that when the dissociating temperature of acetylene (1432° F.) was reached an explosion took place, which also destroyed the tank.

In order to overcome this objection we employ in our system tanks with soft-soldered seams and high-pressure pipes of a material that will melt at a temperature of about 400° F.; that is, 1000° below the danger point for acetylene. These pipes are tested with 600 pounds of pressure, and, in connection with the soft-soldered seam tanks, render an explosion impossible.

Such a tank and pipe, filled with 150 pounds of acetylene, were tested, and neither the heating of the pipe at any particular point nor the heating of the tank in a fire of wood saturated with kerosene oil could produce anything more than a leak by which the gas burned out without damage to the tank.

There is also a safety valve by which the gas escapes when a derailed car turns over on its side.

So far, only those systems of acetylene train lighting have been mentioned in which there is a stationary generating plant, from which the gas, properly generated, cooled and purified, is supplied by a pipe line to the coach yard and thence to the tanks under the coaches.

The idea of generating the gas on the train, or on each car proper, has, after numerous failures, been given up in Europe and Canada, and on some railroads in the United States.

In the following different manners of generating gas on the train, all of which have been tried without success, are mentioned:

First. Lighting a train by placing in the baggage car a generator of sufficient capacity to light the entire train.

Second. Lighting a train by a generator placed in each car, and having tanks under the car in which the gas is stored under pressure from the gas bell, or other contrivance, when being generated.

Third. Lighting a train by a generator placed in each car and using the gas generated directly for lighting without storage. The generator of this class and that of class 2 is either stationary and charged in the cars, or it is removable and is replaced when empty by another generator which has previously been filled at a charging station.

Fourth. Lighting a train by means of generator lamps, whereby each lamp, similar in operation to the well-known bicycle lamp, generates its own gas. The reason for the failure of all these systems, which generate the gas on the train, has already been given.

With generators placed in coaches it is impossible to obtain a dry and purified gas, and, while such devices may be made to work for a short time, stopped-up pipes, stopped-up burners and ultimate failures of the lights always come sooner or later. Such failure has sometimes been accompanied by accidents, due to the fact that when the lights are turned off, or when the water supply is cut off from the generator, the generation of gas is not stopped, and thereby the gas inclosed in the generator or pipes is subjected to a pressure which may wreck the generator.

It is also evident that the charging of a generator on a car is obnoxious on account of the smell, and this operation becomes dangerous when made necessary by an artificial light; while with the storage tank system gas under 150 pounds of pressure is filled in tanks under coaches with all lamps burning.

Systems which employ exchangeable generators are yet more obnoxious, as some gas always escapes when the change is being made and a liability of loose and leaky joints is introduced, while the joints of the stationary car generator are made permanent.

This system is, further, a costly one, requiring more men and a greater number of generators than a system using stationary car generators.

If all these generators have been unsuccessful primarily on account of the quality of the gas generated, very little need be said regarding generator lamps, which usually make a gas of the most vicious kind. Regarding their efficiency, it is to be doubted whether the gas made in such lamps possesses 60 per cent. of the illuminating power of gas properly generated and dried.

It is only with systems which carry their gas supply in tanks with them that the train personnel has absolutely no other duties in connection with the train lighting except that of lighting and turning off the lamps.

In all four of the systems mentioned as making their gas supply on the train, reliance must be placed on the proper attendance of the train personnel for a satisfactory lighting, and this in itself is a grave inconvenience.

As far as economy and efficiency is concerned, none of those systems which make their gas on the train can compare with a system carrying gas in storage tanks.

The initial cost of equipping, say, ten trains, when compared with the system of carrying the gas in storage tanks, is for system 1 much smaller; but, as such a plant would fill nearly the entire baggage car, aside from all the other objections already mentioned, this system has in practice been very little used.

For system 2 the initial cost would be higher, and for system 3, with the exchangeable generator, about equal, on account of having to provide at least two generators for each car.

The initial cost will be less for system 3 with stationary car generators and without storage tanks, and also for system 4, employing generator lamps.

Economy can be had only in the manufacture of acetylene in a central station plant where a gas of high candle power is produced. The entire plant can be run by one man, even if the plant has a daily capacity of 10,000 feet, which is equivalent to more than 30,000 feet of Pintsch gas. A tank under a coach can be filled by unskilled labor in from two to three minutes, and, after this operation is performed, only the lighting and turning off of the lamps remain to be done by the train personnel.

Figures of cost for the different methods of lighting trains have so far not been given, and before entering on this subject it might be well to state here that it is necessary to regard with a critical eye all information regarding cost of lighting, which is only too often furnished by interested or incompetent persons. If this precaution is neglected some rather curious results will follow.

In a paper published some eight months ago in the proceedings of a railway club a statement is given regarding the cost per light per hour for different lighting systems, according to which the lighting with storage batteries is the cheapest of all methods of lighting, not even excepting the lighting with oil, which appears to cost about three times more.

Now, as the life of a storage battery is, at best, only three years, and generally in train service not more than two years, the depreciation of the batteries alone would amount, per candle power, to more than the entire cost stated. It is in fact one of the most expensive methods of lighting a train.

In order to arrive at the true cost of a candle power per hour for any train light, it becomes necessary first to allow for the proper depreciation of the capital invested in stationary plants and train equipment; then to consider the expense for operating same, and finally to provide for renewals and repairs.

As all lamps in electric train lighting have to be renewed several times in one year, and renewals of burners in gas lighting are also necessary, these expenses must appear in a comparative statement of cost. In fact, no item should arbitrarily be considered too insignificant to enter into the estimate of cost, as it might often materially change the final figure.

To light a modern train electrically requires, roughly speaking, about 30 H.P., and yet a company manufacturing apparatus for train lighting states in its circular that the cost for power is so small as to deserve no consideration.

Comparative statements of cost, if not made for the same locality and for approximately the same number of equipped trains, are misleading. It is easily seen that in the former case the difference in cost of supplies in wages and in the total number of lamp hours per year prevents a true comparison, while in the latter case one railroad company having fifteen trains equipped and another company only two, the cost of operation and maintenance per light will be materially affected.

It therefore appears impossible to give the cost per candle power with any degree of accuracy, and figures procured from one particular case should not be set up as averages.

In Chicago Pintsch gas is sold to customers at $5.00 per 1000 feet, delivered in holder under coach. An equal amount of acetylene gas, even when manufactured in a plant of smaller daily capacity than that of the Chicago Pintsch gas plant, can be placed, compressed to the same degree as Pintsch gas, into the holder of a coach at $10.50 per 1000 feet. This price comprises all expenses, including 5 per cent. for depreciation of the plant and 6 per cent. interest on capital invested, with carbide at $68.00 per ton f. o. b. at factory.

Acetylene gas, compared with Pintsch gas, has an illuminating power of 3 to 1; hence acetylene would be 30 per cent. cheaper than Pintsch gas.

Aside from its lower price, there would be the advantage of having, with the same tanks and same pressure as used in the Pintsch system, a three times larger supply of gas on the car. Further, the much greater diffusive power of acetylene will give a superior illumination of a coach.

Acetylene need not fear the competition of electricity in train lighting. Any system of electric train lighting costs more than any system of acetylene lighting. Electric lighting is less reliable, and must therefore be installed with an auxiliary system of lighting, such as oil or gas. Putting the same number of lights in a car, the car lighted by acetylene is the better lighted of the two. The quality of the light given by acetylene is far superior, and, if wanted, acetylene berth lights, acetylene entrance lights, acetylene cigar lighters and acetylene driven fans or any of the other attractions which are placed on a coach for advertising purposes, rather than for the accommodation of the traveling public, may be introduced.

SEWER MAINTENANCE.*

By W. C. Parmley, Member of the Civil Engineers' Club of Cleveland.

In considering the social conditions under municipal organization the sanitary welfare of the people is of the first and greatest importance.

He who spends money for fine paintings while his children cry for bread commits no greater crime than the city which spends vast sums for public conveniences or in beautifying the landscape unless, first, human life and health be well guarded.

In relation to the public health of any city two factors are paramount in importance: First, a pure water supply, and, second, an adequate and efficient system of sewerage. It is to the second of these, the sewerage, that I wish to direct your attention at this time, and more particularly to the maintenance of such system after it has been put in operation.

The city of Cleveland at the present time has a vast network of sewers, aggregating about 257 miles. These sewers already extend their benefits to the greater part of the city, and are rapidly reaching for the outer limits. But, after they are built, what is being done to keep them in a sanitary condition? In the year 1898 the total amount expended for cleaning and repairing was less than $20,000, or, by the annual report of the Superintendent of Streets, $19,592.91, a small amount to keep clean and in order a system costing our citizens over $6,300,000 to build.

It seems well-nigh impossible for man to outgrow the weakness expressed in the saying, "Out of sight, out of mind"; and because a sewer is buried beneath the surface, the mere knowledge that such a conduit exists, no matter what its filth may be, seems to satisfy the general demand. Yet, as our eminent sanitary engineer, Mr. Rudolph Hering, has truly said,† "a sewer will never be anything but a powerful enemy in our midst, and if not under perpetual supervision will some day bring sorrow to our homes. To reduce this evil to a minimum it is absolutely necessary that all works be designed, built and maintained according to the latest and most approved methods of the science of sanitary engineering, and should have far more care bestowed upon them than is generally done or believed to be necessary."

*Manuscript received June 11, 1900.—Secretary, Ass'n of Eng. Socs.

†Proceedings, Engineers' Club of Philadelphia, Vol. I, page 15.

A sewer can no more be built and then left to take care of itself than can a building, a bridge, a pavement or a machine. Because it is buried from sight, and therefore out of mind, it becomes an enemy all the more insidious and dangerous. If the surface of the street becomes foul and unsightly, public sentiment will require its cleansing, but the contents of a sewer may become a putrid and filthy mass and, by the escape of its effluvia into our dwellings through some unknown defect in plumbing, cause irreparable injury before its condition is suspected.

At the present time it seems to be popular, even among engineers, to disarm the old bugbear "sewer gas" of its supposed terrors. While it is acknowledged that there is no such gas, I think no one will contend that the emanations from a foul sewer are wholesome. On the contrary, their effects are so slow and insidious, so secret in their workings, that when their deadly work is done the true cause often remains unsuspected, while a less important and more immediate or noticeable cause bears the blame. Foul air weakens the system, and renders it vulnerable to attacks from disease which otherwise would be harmless. The city of Milwaukee furnishes an illustration of this evil of unclean sewers. The city engineer, from data collected by him, observed a prevalence of disease in portions of the city where sewers were not properly cleaned.

The causes affecting the death rate are complex and varied in the extreme, involving the quality of the water supply, climatic peculiarities, habits of the people in each locality and general configuration and drainage of the surface. The entire sewerage system of any particular city usually receives the same amount of attention, whether that be much or little. It is impossible, therefore, to state numerically just what effect the foulness or cleanliness of sewers has upon the death rate, but all authority is agreed that matter once reaching a sewer should be carried to the outlet before decomposition has begun.

Granted, then, that sewers should be kept fairly clean, we may profitably consider the present method pursued in our city, its defects and some methods of remedying them.

Under the present organization the maintenance of sewers is in charge of the street department, and thus entirely disconnected from the engineering department, under which they were constructed. The street department is also engaged in the duties of cleaning the surface of streets and repairing defects in surface improvements. This field of activities in a large city requires a considerable force of workmen, and the proper and economical management therefore becomes correspondingly difficult. A small force

of men is employed repairing sewers and cleaning catch-basins. Another gang is occupied in flushing and cleaning out sewers where stoppage has occurred. These gangs are liable to a call to any part of the city, and their immediate duties depend entirely upon the urgency of the call. Sewers are inspected and cleaned only upon complaint, or in cases where the department knows that they need frequent attention to keep them in operation.

The defects of this method are many, and for the most part obvious. Among these we may notice:

First. The magnitude of the work of keeping our streets clean is sufficient to occupy one well-organized and well-equipped department.

Second. The street department, having the care and maintenance of the sewers, is entirely disconnected from the engineering department, where all the sewers are designed and where all the records are kept. It, then, does not possess the necessary records, maps and other data to enable it in the most comprehensive and economical way to care for this vast system of sewers.

Third. Owing to the insufficiency of the force and organization of the work, no knowledge is had of the condition of a sewer until some complaint of its foulness is made, or the sewer is entirely stopped by the accumulation of deposit. It thus happens that many, indeed, most, sewers are never examined after they are accepted from the contractor, and it has been found upon examination that in some of the sewers rubbish has lain for years obstructing the free flow of the water.

In many cases mortar dropping from the masons' trowels and adhering to the walls of the sewer has never been removed. The capacity of the sewer is thus lessened, and the tendency to foul deposits greatly increased. While the city was at fault in accepting sewers before the mortar was cleaned from the walls, the fact remains that a large number of our sewers should be thoroughly scraped before they can be properly maintained.

Fourth. In consequence of these facts a large number of our sewers are ordinarily in an unsanitary and filthy condition, endangering the health of the people and liable to produce damage by flooding at times of storms.

Recently something like one hundred examinations of lateral sewers were made to determine the conditions of those cases where the flow of water is insufficient to carry off the heavier matters reaching the sewer. The conditions revealed are difficult to describe, and would naturally startle one not familiar with such sights. In many instances the deposit varied from a few inches to

over a foot in depth, over which meandered, in sluggish, tortuous course, a tiny filament of semi-liquid putrifying filth.

Fifth. The present spasmodic and local methods of flushing too often flush the sediment from one portion of the sewer to some other portion farther down stream, thus making the condition at the latter point worse than before.

Sixth. The condition of our catch-basins is unsatisfactory as now maintained. Under the present system the catch-basins are cleaned by contract at the rate of 59 cents per basin. The contractor cleans those designated, and as often as ordered by the superintendent of streets. About $6000 are spent annually for this work, in addition to cost of repairs and cost of cleaning and flushing inlet connections with these catch-basins, which is done by the street department and charged to the several sewer districts.

It is not known just how many catch-basins there are in the entire city, but the number is estimated at not less than 8000. With the expenditure of only $6000 annually it is easily seen that each basin cannot be cleaned as often as twice a year. As a fact, the basins in localities where they fill up most rapidly are cleaned more often than this, but many other basins are not cleaned as often as once a year. The general result is that during the summer months catch-basins as a rule stand partially or entirely filled with decomposing filth, and the offensive odors arising therefrom are often apparent to the passers on the street.

While it is probable that the cost of about 60 cents for cleaning each basin is not unreasonable, it is painfully evident that they should be cleaned much more often, and that some adequate form of inspection should be maintained in order that they may not stand for weeks at a time as noisome and pestilential spots along our thoroughfares. An annual expenditure of double the present amount would not be too much to keep these appendages to the sewer system in proper condition.

If the "white wings" system of street cleaning were established in our city, the cost for this item of sewer maintenance could be materially reduced and better results obtained.

Seventh. The present method is too expensive, considering the results attained.

To illustrate the actual cost under the present system of flushing sewers, I have chosen several of the cases of work done during the summer of 1899.

These examples show the cost for flushing and cleaning sewers, exclusive of the cost of cleaning catch-basins or repair work on sewers or basins.

The cost for forty-seven cases, taken during the summer of 1899, aggregating about 9.75 miles of sewers, from 12-inch pipe to No. 7 brick, was $1910, or an average of $196 per mile. More in detail we may give the following instances with the conditions and costs, which will be of value in comparing them with the costs of similar work in other cities:

Length, Feet.	Kind of Sewer, Inches.	Grade.	Nature of Work.	Cost per Mile.
960	20, No. 2	0.5	Simple flushing.	$40 70
1625	12—15	0.5	Simple flushing.	104 00
1625	12—15	0.5	Simple flushing.	90 00
912	No. 2	0.25	Sewer nearly filled with fine sand.	2,860 00
721	No. 2	0.3	Ordinary flushing.	79 00
1684	No. 2	0.25	Ordinary flushing.	33 10
2215	12—15, No. 2	0.4 to 0.65	Ordinary flushing.	46 70
3736	12—No. 4	0.3	Ordinary flushing.	55 90
1610	20 and No. 2	0.25	Sand less than 6 in. deep.	96 00
827	No. 2	0.30	Flushing.	67 30
658	12 and 20	0.3 and 0.4	Flushing.	84 80
689	Nos. 5, 6	0.3 and 0.8	Flushing.	26 80
832	15	0.25	Some sand.	101 00
1278	No. 2	0.5	Flushing.	21 80
1007	12	0.5	Some sand.	50 50
1132	12	0.5	Some sand.	73 50
779	12	0.4	Some sand.	84 80
779	12	0.4	Some sand.	190 50
802	12 and 15	0.32	Flushing.	82 20
1662	12 and 20	0.3 and 0.4	Some sand.	29 80
1600	Nos. 2, 4, 6, 7	0.25	Sand 1 in. deep taken out at M. H.	525 00
903	12	0.3	Flushing.	108 00
805	12—15	0.3	Flushing.	80 50
1443	Nos. 1, 2, 3	0.2	Sand 2 in. deep.	104 00
803	12—15	0.3	Flushing.	79 50
649	No. 2	0.5	Flushing.	38 70
873	12	0.3	Flushing.	86 40
1135	12	0.5	Some sand.	91 00
1133	12—15, No. 1	0.2 and 0.3	Flushing.	33 30
341	No. 2	0 25	Depression in sewer, dead water and sand.	860 00
1100	12, No. 2	0.2 and 0.3	Sand 9 in. deep.	299 00
1507	No. 2	0.25	Sand from 3 in. deep to ¾ full.	463 00
587	12—15	0.25	Flushing.	121 00
1012	12—20	0.3 and 0.4	Flushing.	56 80
1643	12, No. 2	0.12 to 0.5	Light flushing.	14 10
1610	20 and No. 2	0.25	Flushing.	51 80
362	15	1%	Flushing.	115 00
585	12	0.7	Flushed rubbish.	518 00
1356	15	0.25 and 0.5	Flushing.	82 00
200	No. 4	0.25	Sand 1½ ft. deep. Sand flushed ahead by hose.	1,128 00
610	No. 4	0.25	Sand 6 in. to 1½ ft. deep, flushed ahead by hose.	1,195 00
1473	15—20, No. 2	0.3 and 0.6	Flushing.	143 50
966	15 and No. 2	0.5	Flushing.	126 50
528	20 Brick	0.5	Flushing.	61 40

In Cleveland egg-shaped sewers have the following elements for those mentioned above:

	Height, Feet.	Width, Feet.	Area, Square Feet.	Hydraulic Radius (Sewer full).
No. 2	2.25	1.94	3.41	0.518
No. 3	2.75	2.23	4.75	0.609
No. 4	3.23	2.54	6.35	0.702
No. 5	3.74	2.95	8.55	0.815
No. 6	4.22	3.33	10 90	0.920
No. 7	4.69	3.69	13.39	1.020

With these figures before us it will be instructive to observe what is the cost for similar work elsewhere. In order to obtain facts in regard to the maintenance of sewers I addressed letters to a large number of our more important cities.

The cost for flushing and cleaning the sewers in the cities named is given in the following table. It seems apparent, however, that in some instances the cost given must include other items, or else there was some error in the figures stated. The fact of whether flush tanks are used or not and the number in use, together with the amount of pipe and brick sewers, is also stated.

TABLE I.

Showing Cost per Mile for Cleaning Sewers.

Name of City.	Yearly Cost per Mile for Cleaning and Flushing.	No. Miles Brick or Storm Sewers in City.	No. Miles of Sanitary or Pipe Sewers in City.	Number and Use of Flush Tanks.
Brockton, Mass	$5.00 for pipe sewers. None for brick.	3.5	17	No
Buffalo, N. Y.	About $158.00	41 1.9		No
Chicago, Ill	$66.98, including cleaning catch-basins.	527	861	20
Dayton, O.	About $12.80 for sanitary system	45	39	Yes
Denver, Col	$53.70	21.95	210.74	151
Indianapolis, Ind	About $88.00 for cleaning and repairing	9 1		Yes
Lowell, Mass	Practically nothing	8 3		No
Minneapolis, Minn	About $53.11, exclusive of catch-basins.	106.03	36.7	82
Madison, Wis	Not more than $5.00	0	21.75	30†
New Haven, Conn	About $15.00 for pipe sewers and $28.00 to $35.00 for storm sewers.	42.6	53.1	No
Newark, N. J.	Pipe, $211.20; brick, $844.80	58.90	92.47	19
New York, N. Y.	Pipe sewers, about $40.30; brick sewers, $20.40	368*	124*	123‡
Paterson, N. J.	About $110.00 per mile for pipe and brick	21	51	No
Rochester, N. Y.	When test pits are necessary, about $500.00 for pipe sewers, and from $750.00 to $1000 for main sewers.	95	121	No
Rockford, Ill	Less than $100.00 per mile	None	22	20
Salt Lake City, Utah	$200.00 for mains	7	27.3	
San Antonio, Tex	$47.30 for brick and pipe	4	70	200
Spokane, Wash	$15.00 to $20.00	0	18.5	65
St. Paul, Minn.	$25.50 for pipe and brick	50.10	103.64	4 or 5
Scranton, Pa	About $80.00; 9-10 being for catch-basins	2.5	46.75	No
Winchester, Mass	$36.00	0	17.1	No
Youngstown, O	$48.40	3 1		Very few

*In Borough of Manhattan. †Used but little. ‡In Borough of Richmond.

While it is apparent that there is a very wide range in the cost per mile in the different cities, depending no doubt upon the local conditions, methods of doing the work, etc., yet on the whole the cost in our city ranges very high, as shown, for the various cases given above. The cause of this excessive cost lies apparent on the surface. In each case where it exceeds a certain amount sand or other deposit has choked the sewer to a considerable degree. Had these sewers been cleaned before the accumulations had become so deep, the cost for several cleanings would not have aggregated so much as for the one cleaning given, and the sanitary results would have been far better. That our sewer cleaners are able to do a given amount of work at a reasonable cost is shown, I think, by the small cost per mile in those cases where the sewers were not seriously clogged by deposit.

This fact suggests in part the remedy for the present method of repair and cleaning work. If the organization and appropriation for the maintenance of this department were adequate to the needs, these sewers would not be allowed to become so obstructed, and the cost for doing the work would then drop to a point comparable with the cost in other cities.

In order to indicate the general methods pursued elsewhere the following table is given, which shows what cities have indicated a preference for flushing with flush tanks and which prefer to use the hydrants. To indicate the kind of sewers and the number of flush tanks in use, these data are also added, as shown:

TABLE II.

Showing Method of Flushing Preferred.

Cities Preferring Flush Tanks.

	Number Flush Tanks in Use.	Miles of Brick Sewers.	Miles of Pipe Sewers.
Atlanta, Ga	150	15	70
Canton, Ohio	73	8	20
Dallas, Texas	50	1	43.2
Denver, Col	151	22	210.7
Lincoln, Neb	94	2.6	39.4
Madison, Wis	*30	0	21.8
New York, N. Y	†123	368	124
Peoria, Ill	‡255	19.8	50.4
Pueblo, Col	70	0	41
Rockford, Ill	20	0	22
San Antonio, Texas	‖200	4	70
St. Paul, Minn	¶4 or 5	50.1	103.6
Spokane, Wash	65	0	18.5
Toledo, Ohio	22	124	18
Trenton, N. J	100	11	21
Topeka, Kan	§27	5.9	41.9
Salt Lake City, Utah	0	7	27.3

*Flush tanks are preferable for flushing.
†To be increased to 158.
‡Only 2 in use owing to litigation with water company.
‖"More reliable but less effective" than hydrants.
¶Preferred "if water is free."
§Wagon tanks are used, but flush tanks are better.

Cities Preferring Hydrants.

	Number Flush Tanks in Use.	Miles of Brick Sewers.	Miles of Pipe Sewers.
Binghamton, N. Y	95	7.8	25
Duluth, Minn	0	2.6	12.3
La Crosse, Wis	*0	1.5	9
Madison, Wis	†30	0	21.8
Newark, N. J	19	58.9	92.5
Spokane, Wash	‡65	0	18.5
Wilmington, Del	10	12	41
Youngstown, Ohio	3 or 4	3	1

*Have had 20 or more.
†Hydrants are best for removal of stoppages.
‡Hydrants best for stoppages only.

It is noticeable that, as a rule, those cities having most experience with automatic flush tanks express themselves as favoring this method, rather than depending upon the spasmodic or even regular use of a stream from a fire hose.

The question of the desirability of building flush tanks in the city of Cleveland is an important one. Our city contains no example of this modern apparatus. There are in the city approximately 950 sewer dead ends, which means that if a flush tank were constructed at the upper end of each lateral sewer the construction of 950 flush tanks would be required. In the near future the number would easily reach 1000. The cost of these 1000 flush tanks would be about $60,000. Suppose that thirty-year $3\frac{1}{2}$ per cent. bonds were issued to pay for their construction, the annual charge for interest would be $2100, and the payment to the sinking fund at the same interest rate, in order to pay the bonds at maturity, would be $1200, making a total annual cost of $3300. The consumption of water, at 300 gallons daily, would be 109,500,000 gallons annually, at a cost of about $650. The cost of repair and maintenance, at 2 per cent., would be $1200. An estimated cost of attendance to keep them in operation, employing, say, five men, each inspecting twenty tanks daily, making a complete inspection about every ten days, at $1.50 per day, would be $2250 per annum. The total cost of providing and maintaining such a system of flushing would thus be about $7400.

At the end of the thirty years the cost would be reduced by $3300, or to $4100 annually, providing the cost of repairs were not increased by rusting away of the cast iron siphons. As some castings would probably need replacing, we may set the average annual charge for maintaining these 1000 flush tanks in operation after the bonds have been paid off at $5000 a year.

The result obtained would be that the terminal portions of all lateral sewers would always be kept in a cleanly and sanitary condition, while the sewers more than 1000 feet downstream from the flush tanks would be only slightly improved thereby.

The use of the hose from hydrants would therefore be necessary on all main lines of sewers where the sediment tends to deposit. Since, however, the principal hydrant flushing that is done at the present time is on the upper ends of the lateral sewers, the cost for this flushing would be considerably decreased.

The proportion of the total expense of maintenance chargeable to this hydrant flushing and cleaning at the present time is not known, since the accounts do not separate it from the general charge for repairs on sewers. That much more in this line should be done is evident from the generally foul condition of the sewers.

In comparison with the work that would be performed by the 1000 flush tanks, we may estimate that four gangs of three men each, with light wagons and apparatus, could flush all the sewers from the dead ends at least once a month. The scouring effect of each flushing would be greater than that obtained from the flush tanks, and would extend downstream a greater distance. The cost of this force annually would be about $7200, or approximately the same as the cost of maintaining the flush tank system. If such a system were inaugurated I believe that the amount of flushing required on the downstream reaches of our sewers would be comparatively small.

While not prepared to advocate the immediate construction of 1000 flush tanks, in my opinion it would be a good policy to build tanks at such points as show a special tendency to become foul.

The number to be built would be determined from examination of each individual lateral. Supplementing these with systematic flushing monthly, as indicated, of all dead ends not so provided would revolutionize the condition of our sewers.

It is common with us to let out the more important repair jobs to contractors. As showing in what favor elsewhere this method is held, I found that out of fifty-eight cities only five—viz, Buffalo, Erie, Philadelphia, Troy and Youngstown (Ohio)—let sewer repair work by contract. All the remainder of the cities reporting do all of this work by a regular force in the employ of the city cleaning and repair department.

Indeed, we do not need to go elsewhere to learn that the city can economically do this work. In May, 1899, a serious break occurred in the steep outlet portion of the Ontario street sewer. After a length of 66 feet, requiring almost no excavation, was rebuilt by contract at $14 per lineal foot, it became necessary to rebuild about 144 feet more of the sewer lying at a depth of about 20 feet. For this latter work the lowest bid was $22 per foot, or a total of $3168. The bid was rejected, and the work performed by the sewer department at a total cost of $1960, or at $13.60 per foot, thus saving over $1200.

If, therefore, our present method of flushing and repairing sewers be defective, what kind of an organization would be most efficient, and under what department should it operate?

As an aid in solving the latter question, I find, upon examining the data at hand pertaining to other cities, that the maintenance of sewers is either under the street cleaning or public works departments, under a specially organized sewer maintenance department, or directly under the chief engineer.

An examination of the cases falling under each of these four headings, to discover if possible under which method the best results are obtained, reveals interesting results.

Of sixty-one cities considered, I find twelve where sewer maintenance is under the street department, twelve where the report shows it to be directly under a public works department, twenty under the sewer department and seventeen under the city engineer.

In the first and third classes we find the cities of first rank in importance and population, the two other classes representing cities of medium size.

The cities in each class were graded "good," "fair" or "bad," depending upon the general results obtained, judging by the information received. Those rated "good" are cities where regular inspection and flushing is carried on, and where the sewers at all times are kept in a sanitary condition. Under "fair" are included those cities having less regular and frequent flushing and inspection, and where apparently some of the sewers at times are not in good order. The term "bad" is applied to those cities where there is no regular inspection; where the cleaning is carried out only upon stoppage of the sewer, or where complaint is made of back flooding or other sewer troubles. The result shows:

	Good.	Fair.	Bad.
Street Department	1	5	6
Public Works Department	1	4	7
Sewer Department	9	10	1
City Engineer	6	7	4

By this comparison two things are clearly brought out,—viz, first, the inefficient maintenance when the care of the sewers is under a street cleaning department, where the attention primarily is given to keeping the surfaces of the street in proper condition, and, second, the comparatively good results obtained when sewer maintenance is under a sewer department, in which the care of sewers is the one business in hand. The cities under the city engineer show good results, because in those cases the work is usually divided between sub-departments, each with regular assigned duties.

The sewer department is usually a subdivision of the public works or of the city engineer's department, it being rather immaterial for our purpose by which of these departments the work is done, because either is a definite organization created for definite work, and may reasonably be supposed to perform efficiently its own special duties. Since with us city engineering is a subdivision of the public works department, the obvious lesson from the above

observations is that the work of cleaning and repairing sewers should be a subdivision under the chief engineer. Coming, then, to a statement of what would appear to be an efficient organization, we may mention:

First. The entire matter of maintaining our sewerage system should be under the general direction of the chief engineer.

Second. Directly in charge of the work there should be a competent civil engineer, whose training and experience fit him for this special work.

Third. The city should be divided into several districts, for the purpose of securing more complete and thorough work.

The outlines of these districts for the most part would follow the lines of division between the different drainage systems, but several outlet main sewers with their laterals might be embraced in one district.

The boundaries of these areas could easily be modified at any time should such modification be found to simplify the work of inspection and repair.

Fourth. Each district should be under the care of a competent inspector, with such assistance as experience may show to be necessary. These inspectors need not be engineers, but intelligent workmen who are able to understand the work and who are able to direct the workmen engaged.

Fifth. Require frequent and regular inspection of all sewers and catch-basins. The frequency in some cases would be greater than in others, but it is safe to say that every sewer should be inspected and flushed, if necessary, as often as once a year, and most of the sewers much oftener. Some sewers which are known to cause special trouble and the upper portions of lateral branches should be given even more frequent attention. Otherwise, in general, the inspection and flushing should begin at the remote laterals and progress systematically downstream to the outlet.

Sixth. A sufficient number of flushing and repair gangs should be provided for each district, who report directly to the assistant engineer in general charge. This engineer assigns their daily duties in accordance with the reports received by him from the several inspectors.

Seventh. An adequate system of accounts should be kept, showing the cost of the work in each particular case, and a record kept where the cost is equitably apportioned among the several legal sewerage districts of the city. In order to do this work in a city of this size a competent clerk would be necessary.

Eighth. An adequate annual appropriation should be made by the City Council for the maintenance of our sewers, and should be none the less because the results obtained are not apparent to the eye of the ordinary citizen. In a large degree the healthfulness of our city depends upon the faithfulness with which this work is done.

From a consideration of the facts shown in Table I, and from the experience of other cities, it would appear that an annual appropriation of $50 per mile for flushing and cleaning sewers, in addition to the appropriation for repairs and the cleaning of catch-basins, would not be unreasonable for the purpose of keeping the sewers in a proper condition. This appropriation of, say, $15,000, added to an average of $20,000 for repairs and cleaning of catch-basins, or $35,000 for the entire city, is about 5 per cent. annually on the original cost of the work, as the cost of keeping the sewers clean and in repair. No other class of structures can be maintained at so small a percentage of their cost, and the people of an intelligent city ought not to object to so slight a tax in consideration of the improved healthfulness of the city.

"Gold that buys health can never be ill spent."

DISCUSSION.

Mr. M. E. Rawson.—I fully agree with Mr. Parmley, who has given the matter careful thought, that all cleaning, repairs and renewals of sewers, flush tanks and basins throughout the entire system of sewers should be under the supervision and care of the engineering department, which plans and constructs them; not only because the engineer who plans and constructs this work will be more zealous of its care and anxious for its success than any one else, but because he has all plans showing sizes, depths and gradients of the sewer at his command for ready reference, as to the kind and nature of the repairs most needed and most economical.

The cleaning and repairing of all sewers in this city is now being done by the street department; too frequently with unskilled men, certainly by men without a full knowledge of the sizes, depths, direction of flow or manner of original construction of the sewers and basins they are sent to repair, and without that interest which the engineer would have. I have frequently known instances in point where an ignorant laborer has broken out a submerged catch-basin trap because, standing on top of the basin, he could see no way for the water to get out.

Too frequently it is easier to fill up a hole in the street, caused by a break in the arch of a sewer, than it is to go inside the sewer,

find the cause of the trouble and make the repair thorough and lasting.

The fine yellow sand upon the surface of most of our streets, and the almost inevitable presence of very fine blue quicksand underneath, encountered in the construction of almost every sewer in this city, are insidious foes to good construction of sewers and to their care and maintenance afterwards.

The present practice of flushing sewers by the street department is often a detriment rather than a benefit, as, while it may remove the sediment or obstruction from the front of one owner's residence, it is only to pile the sand up in front of his neighbor and does not remove it from the sewer.

As to the desirability or necessity of using automatic flush tanks for keeping the sewers in good sanitary condition, the distinction should be made between a city like our own, where the storm water is depended upon, either wholly or in part, to flush the sewers, and other cities and villages where the sewage flows in one sewers and the storm water in a separate one. In this latter case flush tanks or similar devices are an absolute necessity. In the former case, as in Cleveland, flush tanks may be desirable, but with us there is not the same necessity for them, and they have never been used.

Mr. Parmley.—The question of whether flush tanks are or are not a necessity depends upon our understanding of the word. After examining one hundred or more of the terminals of our sewer system in those localities where, if anywhere, they should be in good order, in the month of December, after the flushing effect of the fall rains, and finding in every instance from a few inches to a foot of putrifying matter in the bottom, with a tiny stream flowing over the surface, in my opinion the flushing of our sewers may be considered necessary. Only occasionally will sewers become so clogged that the flow is actually stopped, but every principle of sanitary science requires that, so far as possible, deposits in them be prevented. This can be done only by keeping the terminals flushed, either automatically or otherwise, frequently enough to prevent the formation of deposit and the decomposition of organic matter in the sewer.

Mr. J. C. Beardsley.—Does the flushing of paved streets have an injurious effect on the sewers?

Mr. Parmley.—Only when the grade of the sewer is flat and when the volume flowing is small. Most of our main sewers in the downtown portion of our city are on sufficient grade, and have volume of flow enough to carry away the rubbish from the streets.

Mr. W. L. Cowles.—I was surprised to learn of the large number of flush tanks, about 1000 I believe, which would be required to supply Cleveland completely with this service, especially in view of the small number in use in other large cities. Is there any other city where this system has been installed with the completeness implied by the number indicated for Cleveland?

Mr. Parmley.—I know of no city where as many as 1000 flush tanks have been installed. It is not my intention to advocate the immediate construction of that number of tanks for this city. The figures and calculation were given in order to make a comparison with another system of flushing. It is my opinion that flush tanks should be placed at the upper ends of some of our laterals. The number ultimately to be operated could be determined by the success attending other methods of flushing. I am thoroughly convinced that a much more efficient method of flushing sewers should be carried out than that now in vogue.

Association of Engineering Societies.

Vol. XXIV. JANUARY, 1900. No. 1.

PROCEEDINGS.

Engineers' Society of Western New York.

Regular Meeting, January 8, 1900.—Meeting called to order at 7.35 p.m.; Mr. Haven, President, in the chair.

The following members present: Haven, Knighton, March, Ricker, Tutton, Diehl, Bardol, Buttolph, Morse, Tresise, Cornell, Vander Hoek, Roberts, Fields.

The minutes of the last regular meeting were read by the Secretary, and were approved with the following correction by Mr. Haven: The tellers informally reported that Mr. Tresise had been elected Librarian, but in looking over the ballots it was found that this was an error, and on the formal report it was found that Mr. Knighton had been elected.

Mr. Tutton, representing the Society upon the Board of Managers of the Association of Engineering Societies, presented letters from Prof. Geo. D. Shepardson, of which the following are abstracts:

"I have the pleasure of announcing an application for membership in the Association by the Engineers' Club of Cincinnati, which has a membership list of about 111, including 1 honorary, 95 active and 14 associate members. Their report for 1897 shows 10 meetings, at which 13 papers were read."

"During the year we have already added the Engineers' Society of Western New York and the Louisiana Engineering Society."

"It gives me great pleasure to announce as the result of the ballot for officers of the board for the ensuing two years: Whole number of ballots cast for Chairman, 15; James Ritchie, Cleveland, 12; scattering, 2; for Secretary, John C. Trautwine, Jr., 15. Mr. Ritchie is therefore duly elected Chairman, and Mr. John C. Trautwine, Jr., is duly elected Secretary of the Board of Managers."

Mr. Tutton, Librarian for 1898-99, reported as follows:

To the President and Members of the Engineers' Society of Western New York:

Our library to-day consists of about 150 bound volumes, and about 300 pamphlets, many of which should be bound.

We subscribed for nine periodicals in 1896. This was cut down to six

in 1897-98, and for the coming year to four,—namely, *The Engineer, Engineering Magazine, Water and Gas Review* and *Power*.

We receive from various societies, etc., the JOURNAL OF THE ASSOCIATION, *Transactions of A. S. C. E., A. S. M. E., A. I., Elec. Engr.*, also *Proc. Canadian Society of C. E., Western Soc. of Engineers, Engineers' Club of Philadelphia, Engineers' Soc. of W. Pennsylvania, Journal of Water Works Assns., The Brick Builder.* We have been receiving papers from the Smithsonian Institute, relating to Civil Engineering; Chief Engineer's Report, War Department. Some special volumes from the Engineering Department, United States, Coast and Geodedic Survey, United States Department of Agriculture, Forestry Division and Timber, United States Consular Reports, etc. We have been receiving these without any return.

The donors to the library have been Messrs. Geo. A. Ricker, T. Guilford Smith, the New York State University, B. F. Sturtevant & Co. in 1898-99.

I would again call the attention to the By-laws requiring a copy of papers read before the Society to be deposited with the Librarian. This has not been complied with. The amount of papers read during the past year, however, would not make this task onerous.

The Librarian was directed by the Chair to procure the maps of the Geological Survey, issued by the United States, and other Government publications.

MR. HAVEN.—The By-laws state that the Executive Committee shall make a report annually to the Society. As there has been no report made by them for the last two years, I will ask the Secretary to read the minutes of the Executive Committee for the past two years. Minutes read by the Secretary in accordance with the above.

On motion of Mr. Ricker the Chair appointed Messrs. Ricker, Bardol, Vander Hoek, Houck and Guthrie a committee to investigate the status of delinquent members and report to the next meeting.

Mr. Tutton offered this resolution:

Resolved, That it is the duty of the Secretary, without further authority from the Society, to drop from the mailing list of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES at the beginning of each year the name of any member who has not paid his dues for the preceding year, and the Secretary shall immediately call the attention of the delinquent member to this resolution.

Further, whenever a member shall pay up his dues, his name shall be restored to the JOURNAL mailing list. Seconded by Mr. Diehl, and carried.

On motion of Mr. Tutton it was ordered that a committee of five be appointed, of which the Chair shall be chairman, to draft amendments to the Constitution and By-laws, and report at the regular May meeting of the Society.

Meeting adjourned, on motion of Mr. Morse, at 10 P.M.

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., JANUARY 15, 1900.—The sixteenth annual meeting of the Civil Engineers' Society of St. Paul was held in Parlor B, Windsor Hotel, at 8.30 P.M.; President Estabrook in the chair. Fifteen members and nine visitors present. Minutes read and approved.

The annual reports of the officers were read and accepted. On recommendation of the Government of the Society, the dues for 1899 were remitted. The Librarian was authorized to have the periodicals of the past year bound. The Secretary was directed to make the usual arrangements for the care of the Society room.

The following officers were elected:

President—Capt. A. O. Powell.

Vice-President—A. W. Münster.

Secretary—C. L. Annan.

Treasurer—A. N. Hogeland.

Librarian—C. A. Winslow.

Representative on Board of Managers of the Association of Engineering Societies—Geo. L. Wilson.

Mr. W. A. Truesdell read a paper on the "Life of Archibald Johnson," late member of the Society. After adjournment a social hour was spent in the dining room.

C. L. Annan, *Secretary.*

Detroit Engineering Society.

The 44th Regular Meeting of the Society was held at the Hotel Ste. Claire, Friday, November 24, 1899; President Keep presiding.

Messrs. William Scott, J. H. Galwey and F. T. Barcroft were elected to membership.

Messrs. Dunlap, Molitor, Field and Russell spoke on subject of exerting influences of the Society in appointment of members of the Board of Public Works of the City of Detroit. Mr. Dunlap introduced the following resolution:

"That a committee of three be appointed by the Chair to draw up a platform or statement of principles of this Society in regard to the desirable constitution for the Board of Public Works, with reasons therefor; this committee to report to the Executive Committee as soon as possible and the Executive Committee be given full authority to act thereon."

The motion was carried and the Chairman appointed Messrs. Wisner, Dunlap and Molitor.

The address of the evening was read by Mr. Mattsson on "Lake Transportation." The paper was discussed by Messrs. Wilkes, Field, Russell, Tippey, Wisner and others.

Adjourned at 9.45. T. H. Hinchman, Jr., *Secretary.*

The 45th Regular Meeting of the Society was held at the Hotel Ste. Claire, December 22, 1899. Minutes of the last meeting read and approved.

Mr. G. S. Williams was elected member of the Board of Managers of the Association of Engineering Societies to represent this branch.

Mr. F. A. Little was elected a member of the Society.

The Executive Committee reported the deliberations of the Legislative Committee to the Society for action. The report was read in full. Mr. McMath moved (seconded by Mr. Field) that the report be forwarded as per resolution. Motion was lost after discussion.

Paper by Mr. Keep on "Impact" with discussion by Messrs. Greene, Ziwet, McMath, Dow, Field and others followed.

Adjourned at 11.30.

T. H. Hinchman, Jr., *Secretary.*

Detroit, Mich., January 26, 1900.—The forty-sixth regular meeting of the Society was held January 26, 1900; President Keep presiding. Approximately twenty-five members were present to hear the paper by Mr. Chas. L. Weil, professor of mechanical engineering at the Michigan Agricultural College, entitled "Notes on Construction of Underground Systems of Steam Piping." The paper treated on prominent installations in Kalamazoo, Lansing, Boston, New York and other places. A very interesting discussion followed, in which Messrs. Cooley, Hubbell, Torrey and others participated. After the discussion a vote of thanks was moved and carried, and Professor Weil and those who took part in the discussion were requested to reduce their remarks to writing for publication in the journal of the Society.

Meeting adjourned at 10.45. T. H. Hinchman, Jr., *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, December 5, 1899.—Called to order at 8.30 p.m. by President Percy.

The minutes of the last regular meeting were read and approved.

Mr. Harry Larkin, San Francisco, was duly elected an associate member upon count of ballots.

The President announced the death of H. H. Hirst, a member, who died on December 23, and appointed a committee consisting of Professors Frank Soule and H. I. Randall to draw up a memoir of the deceased member to be read before the Society and published in the Journal.

The Nomination Committee, through its Chairman, Mr. C. E. Grunsky, submitted the following ticket of officers for the ensuing year:

For President—G. W. Percy.

For Vice-President—Louis Falkenau.

For Secretary—Otto von Geldern.

For Treasurer—E. T. Schild.

For Directors—Hermann Barth, T. W. Brooks, A. E. Chodzko, E. F. Haas and S. C. Irving.

Upon motion, the ticket was accepted and the Secretary instructed to prepare the ballots for an election to be held at the annual meeting, January 19, the tellers to be appointed before that date.

Mr. P. E. Lamar, member Technical Society, thereupon addressed the Society on the subject of "Work of the Army Engineer during the Philippine Campaign," relating personal experiences and observations.

Adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

500TH MEETING, JANUARY 5, 1900.—Meeting was called to order at 8.15 P.M.; President Chaplin presiding. Twenty two members and one visitor were present. The minutes of the 498th and the 499th meetings were read and approved. The minutes of the 283d and 284th meetings of the Executive Committee were read. There being no miscellaneous business, the paper of the evening, on "The Pollution of Rivers," was presented by Prof. J. L. Van Ornum.

The paper proved of exceptional interest in view of its practical bearings upon some of the successful methods for the prevention of contamination of rivers and their significance to the problem now confronting St. Louis. An historical sketch was given showing how, in early times, people were engaged with the solution of this all-important question, purifying sewage by irrigation or using it for fertilizing purposes. In later years attempts were made to dilute the sewage with water, believing that with a definite flow of water a harmless mixture would result, with no contamination. Yet some of the largest European cities have been obliged to establish filtration plants, as even 9 cubic feet of water per second per thousand inhabitants, or about three times the dilution proposed by Chicago, has been found inadequate and dangerous.

The discussion provoked by the reading of this paper was unusually active and was participated in by Messrs. Chaplin, Flad, Hermann, Ockerson, Freeman, Russell, Spencer, Layman and Bryan.

A motion was made, seconded and carried that a committee of three members be appointed by the Chair to invite the co-operation of other organizations in the city, to consider the action necessary to secure the filtration of the city's water supply and report their action to the Club for consideration. The Chair appointed Messrs. Spencer, Van Ornum and Ockerson on the committee.

A motion was also made and carried that copies of Mr. Colby's paper, on "Water Pollution," read at the annual dinner, and Prof. Van Ornum's paper, on "The Pollution of Rivers," of January 3, be forwarded to the Missouri Congressmen, at Washington, D. C., for useful reference and information in the pending case of the Chicago drainage canal.

Adjourned.

F. E. BAUSCH, *Secretary.*

501ST MEETING, JANUARY 17, 1900.—Meeting was called to order at 8.25 P.M.; President Chaplin presiding. Nineteen members and two visitors were present. The minutes of the 500th meeting were read and approved. The minutes of the 285th meeting of the Executive Committee were read.

The application of Mr. Chas. Fremont Sturtevant was read and referred to Executive Committee.

The committee of three appointed to invite the co-operation of other organizations in the city to consider the action necessary to secure the filtration of the city's water supply made a verbal report. About thirty prominent organizations had been communicated with and replies received from most of them, stating that similar committees had been appointed and efforts were

being made to secure some united action in the matter. It was suggested to include among the list of clubs the Wednesday Club.

The question of a change of quarters for the Club was discussed, but action deferred until further investigation could be made.

The subject of the evening for discussion was then led by Prof. J. H. Kinealy, on "What Degrees Should be Conferred by Schools of Engineering in the Universities of America?" A paper was read giving the results reached by the committee of three appointed by Washington University to arrive at some standard by which degrees should be granted thereafter by the university. The committee's recommendations were that the degree of Bachelor of Science be conferred at the end of four years' work at the school of engineering. After one more year's study in the university and the presentation of a thesis, the degree of Master of Science should be granted. Two more years' work and the presentation of an acceptable thesis, the degree showing the result of original investigation, entitles the applicant to a degree of Doctor of Science. The professional degrees C.E., M.E. and E.E. are given to those holding bachelor degrees from Washington University after three years of professional work, one of which has been in responsible charge of important work, and the presentation of a thesis showing ability to design and execute. These requirements are now in force at Washington University. The discussion which followed was participated in by Messrs. Moore, Humphrey, Bryan, Colby, Layman and Bonton.

Prof. E. A. Englerdean, of the School of Engineering of Washington University, was the invited guest, and gave an interesting account of the condition of things at the European universities, not excepting our own university. The results of a thorough investigation by the committee of Washington University led to the adoption of a rational standard by the authorities of the university, which it is hoped may be emulated by other institutions of its kind.

Adjourned. F. E. Bausch, *Secretary.*

Engineers' Club of Cincinnati.

12th Annual Meeting, Cincinnati, Ohio, December 21, 1899.—Dinner was served at 6.30 p.m. Twenty-six members present. Regular meeting called to order at 8 p.m.; Vice-President Punshon in the chair.

Minutes of the meeting of November 16 were read and approved.

Application for active membership was presented by Mr. Joseph L. Fritsch.

On ballot being taken Mr. W. W. Coney was elected an associate member.

The reports of the Secretary and Treasurer for the year 1899 were presented, ordered received and printed, together with a revised list of members for distribution.

The Secretary's report shows that there was at least one, sometimes two, papers at each meeting; that the average attendance was eighteen against fifteen and seven-tenths for the previous year; that the membership at the end of the year was ninety-seven, a reduction of six from the previous year, eleven new members having been received, one member deceased, ten mem-

bers resigned and six members having been dropped from the rolls of the Club for non-payment of dues.

The Treasurer's report shows total receipts to be $744; disbursements, $609.15; balance on hand, $295.95.

Officers for the year 1900 were elected as follows:

President—Thomas B. Punshon.

Vice-President—Wm. C. Jewett.

Directors—A. O. Elzner, L. E. Bogen and Alfred Petry.

Secretary and Treasurer—J. F. Wilson.

Member Board of Managers Association of Engineering Societies—Thos. B. Punshon.

Mr. A. O. Elzner read a very interesting paper on "The Commercial Value of Art."

J. F. Wilson, *Secretary.*

111th Regular Meeting, Cincinnati, O., January 18, 1900.

Dinner was served at 6.15 P.M.

The regular meeting was called to order at 7.15 P.M.; with President Punshon in the chair, and thirty members and several visitors present.

Minutes of the annual meeting, held on December 21, 1899, were read and approved.

On ballot being taken Mr. Joseph L. Fritsch was elected an active member of the Club.

As the paper for the evening, by Mr. R. L. Read, had been announced for 8 o'clock, and as some of those who had been invited to be present were expected to be on hand at that hour, a recess was taken.

At 8 P.M. the meeting was again called to order and Mr. Read proceeded to the reading of his paper, on "One of the Various Schemes Proposed for Improving the Ground Occupied by the Canal in Cincinnati."

The scheme outlined in the paper, which was presented for the purpose of provoking discussion on the subject, in view of pending legislation touching it, provided for abandoning the canal from about Fourteenth street to its terminus at Court and Broadway, converting that part into a boulevard, with a conduit underneath for carrying water for maintaining present water rights, and constructing a railroad track along one side of the canal from a point at about the northern limits of the city to Fourteenth street, for the purpose of reaching the various industries and improving and developing the property in that territory for manufacturing and other business.

Mr. Wm. A. Gregg, Canal Collector, and Attorney John M. Smedes, a member of the Business Men's Club, who were present by invitation, both spoke against any abandonment of the canal, citing figures and statistics showing the large volume of business carried on it and its value as a transportation line and as a factor in controlling rates by rail.

Mr. M. D. Burke reviewed the question of the proposed construction of a ship canal from the lakes to the Ohio River, and other members of the Club discussed various features of the scheme suggested by the paper.

Adjourned.

J. F. Wilson, *Secretary.*

Civil Engineers' Club of Cleveland.

Report of January Meeting.—Regular meeting called to order at 8.10 p.m. by President J. A. Smith. Present twenty-five members and twenty-five visitors.

August A. Honsberg and William O. Henderer appointed tellers to canvass ballots for Harry L. Olmstead, who was elected an active member.

Applications for active membership of Frank E. Bissell, Edward M. St. John and James N. Hatch were read and referred to letter ballot.

Messrs. Wm. H. Searles, F. C. Osborn, F. S. Barnum, W. R. Warner, August Mordecai, James Ritchie and Ambrose Swasey were elected as a committee to nominate officers for the year 1900-1901.

After a short recess, Arthur C. Johnston, member of the Club, read the paper of the evening, entitled "Dock Equipment for the Rapid Handling of Coal and Ore on the Great Lakes."

Numerous drawings and photographs were shown. The paper was briefly discussed by Messrs. Jno. N. Coffin, J. R. Oldham, A. C. Johnston, Alexander Hynd, L. B. Hoit and C. O. Palmer.

Adjourned at 10 p.m.

Arthur A. Skeels, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., December 20, 1899.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 8 o'clock p.m.; President C. Frank Allen in the chair. Seventy-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Charles F. Janes, James A. McKenna, Henry J. Reynolds and Irving S. Wood were elected members of the Society.

On motion of Mr. Metcalf, the thanks of the Society were voted to the Boston Electric Light Company, and to the George Lawley & Sons' Corporation, for courtesies extended this afternoon on the occasion of the visit to the works of these companies.

The Secretary stated that it had come to his knowledge that the Canadian Society of Civil Engineers would probably visit Boston during the first week in February next, and he suggested that it might be desirable for this Society to take some action looking towards the entertainment of the members of that Society on that occasion.

On motion, it was voted that the Board of Government be given full powers to make whatever arrangements seemed to them best in the way of extending courtesies to the members of the Canadian Society of Civil Engineers.

Mr. William B. Fuller then read the paper of the evening, entitled "Sand Filter Beds and Steel Conduit of the Albany, N. Y., City Water Works," which was fully illustrated by lantern views.

Mr. John H. Gregory, C.E., who has had charge of the filter beds

since their construction, was then introduced and gave some very interesting statistics with regard to the working of the beds.

After passing a vote of thanks to Mr. Gregory, the Society adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., JANUARY 12, 1900.—A special meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 8 o'clock P.M.; Vice-President T. Howard Barnes in the chair. Fifty-three members and visitors present.

The paper of the evening was read by Mr. A. H. French, describing the construction of the Longwood Avenue Bridge, between Boston and Brookline. The paper was profusely illustrated by lantern views.

Adjourned.

S. E. TINKHAM, *Secretary.*

List of Members of the Associated Societies.

Abbreviations for designating membership:

For Honorary Member.......................Hon. Mem.
For Member.......................Mem.
For Associate Member.......................Assoc. Mem.
For Junior Member.......................Jun. Mem.

Boston Society of Civil Engineers.

Adams, Edward P., Mem.,
Landscape Architect and Civil Engineer,
53 State street, Room 1104, Boston, Mass.

Adams, Henry S., Mem.,
Civil Engineer, 53 State street, Room 542, Boston, Mass.

Addicks, Walter R., Mem.,
Chief Engineer, Boston, Bay State, Brookline and other local gas companies, 24 West street, Boston, Mass.

Aiken, Charles W., Mem.,
Consulting and Contracting Engineer, 79 Milk street, Boston, Mass.

Allard, Thomas T., Mem.,
Assistant Engineer, Metropolitan Sewerage Commission,
Residence, 114 Lonsdale street, Ashmont, Mass.

Allen, C. Frank, Mem.,
Professor of Railroad Engineering, Mass. Inst. of Technology,
Boston, Mass.

Allen, Charles A., Mem.,
Consulting Engineer, 44 Front street, Worcester, Mass.

Andrews, David H., Mem.,
Proprietor Boston Bridge Works, 70 Kilby street, Boston, Mass.

Appleton, Ellery C., Mem.,
Civil Engineer, Westboro, Mass.

Appleton, Thomas, Mem.,
Chief Engineer, Copper Range R. R., Houghton, Mich.

Armstrong, Samuel G., Mem.,
Civil Engineer, Box 2139, Johannesburg, South Africa.

Aspinwall, Thomas, Mem.,
Aspinwall & Lincoln, Civil Engineers,
120 Tremont street, Room 606, Boston, Mass.

Atwood, Joshua, 3d, Mem.,
Civil Engineer, 158 Foster street, Brighton, Boston, Mass.

Badger, Frank S., Mem.,
Asst. Engineer, Continental Filter Co.,
35 Wall street, Room 24, New York, N. Y.

Bailey, Ernest W., Mem.,
City Engineer, City Hall, Somerville, Mass.

Bailey, Frank S., Mem.,
Assistant in Engineering Department, Massachusetts State Board of Health, 140 State House, Boston, Mass.

Bailey, William M., Mem.,
Assistant Engineer, Concord Sewers, Concord, Mass.

Baker, William E., Mem.,
General Superintendent, Manhattan Ry. Co.,
10 Dey street, New York, N. Y.

Baldwin, Loammi F., Mem.,
Civil Engineer, 31 Milk street, Boston, Mass.

Bancroft, Lewis M., Mem.,
Superintendent of Water Works, Reading, Mass.

Barbour, Frank A., Mem.,
Snow & Barbour, Civil and Sanitary Engineers,
1120 Tremont Bldg., Boston, Mass.

Barnes, Rowland H., Mem.,
Pierce & Barnes, Civil Engineers, 7 Water street, Boston, Mass.

Barnes, T. Howard, Mem.,
City Engineer, City Hall, Medford, Mass.

Barnes, William T., Mem.,
Resident Engineer, B. and O. S. W. Ry., Olney, Ill.

Barrows, Harold K., Mem.,
With Metropolitan Water Board, 193 Warren ave., Boston, Mass.

Barrus, George H., Mem.,
Expert and Consulting Steam Engineer,
95 Milk street, Boston, Mass.

Bartlett, Arthur, Mem.,
Assistant in City Engineer's Office, City Hall, Lowell, Mass.

Bartlett, Charles H., Mem.,
Bartlett & Gay, Civil and Hyd. Engineers, 852 Elm street, Manchester, N. H. Also Acting Eng., Charles River Iron Works,
9 Concord Square, Boston, Mass.

Bartram, George C., Mem.,
N. E. Eng., Edge Moor Bridge Works,
13 Exchange street, Boston, Mass.

Bateman, Frederic W., Mem.,
Parker & Bateman, Civil Engineers, Clinton, Mass.

Bateman, Luther H., Mem.,
Assistant to Engineer, Harbor and Land Commissioners,
131 State House, Boston, Mass.

Baxter, Charles F., Mem.,
Real Estate and Landscape Engineer,
15 Court Square, Room 72, Boston, Mass.

Bayley, Frank A., Mem.,
Civil Engineer, 133 Austin street, Cambridgeport, Mass.

BEMENT, ROBERT B. C., Mem.,
Civil Engineer and President, Board of Water Commissioners,
St. Paul, Minn.

BETTON, JAMES M., Mem.,
Henry R. Worthington Hydraulic Works, Brooklyn, N. Y.

BIDWELL, LAWSON B., Mem.,
Assistant Engineer, Eastern Dist., N. Y., N. H. and H. R. R.,
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Care First Army Corps, U. S. A., Matanzas, Cuba.

Scarborough, F. W., Act. Mem.,
Signal Engineer Chesapeake and Ohio Ry., Richmond, Va.

Schreiber, Chas. C., Assoc. Mem.,
Vice-President and General Manager L. Schreiber & Sons Co., Mfrs. of Architectural Iron Works,
Eighth street and Eggleston ave., Cincinnati, Ohio.

Siefert, Frank J., Act. Mem.,
Engineer Department Board of City Affairs,
City Hall, Cincinnati, Ohio.

Stanley, H. J., Act. Mem.,
Civil Engineer,
N. E. cor. Eighth and Plum streets, Cincinnati, Ohio.

Stewart, Jas. A., Act. Mem.,
Civil Engineer, 517 Johnston Bldg., Cincinnati, Ohio.

Strack, T. P., Assoc. Mem.,
Wilson & Strack, Contractors,
Ninth and Plum streets, Cincinnati, Ohio.

Stuart, A. A., Act. Mem.,
Secretary of The Cobleskill Quarry Co.,
No. 1 Broadway, New York, N. Y.

Totten, A. L., Act. Mem.,
Civil Engineer, 30 Woodland ave., Lexington, Ky.

Totten, W. H. D., Assoc. Mem.,
Resident Agent for Carnegie Steel Co., Lim., Pittsburg, Pa.,
Neave Bldg., Cincinnati, Ohio.

Venable, M. W., Act. Mem.,
Civil Engineer, 56 Capitol street, Charleston, W. Va.

Venable, W. M., Act. Mem.,
With National Contracting Co., 11 Broadway, New York, N. Y.

WALSH, M., Assoc. Mem.,
Superintendent Bridges and Buildings, C., N. O. and T. P. Ry. Co., Somerset, Ky.

WALTER, HARRISON B., Act. Mem.,
General Contractor, 809 Broadway, Cincinnati, Ohio.

WARDER, R. H., Assoc. Mem.,
Park Superintendent, City Hall, Cincinnati, Ohio.

WARRINGTON, H. E., Act. Mem.,
Assistant Engineer, Cincinnati, New Orleans and Texas Pacific Ry. Co., Odd Fellows' Temple, Cincinnati, Ohio.

WHINERY, SAMUEL, Act. Mem.,
Vice-President Warren-Scharf Asphalt Paving Co., 81 Fulton street, New York, N. Y.

WHITE, I. F., Act. Mem.,
Superintendent Track and Structures, Cincinnati, Hamilton and Dayton Ry., Hamilton, Ohio.

WILSON, C. A., Act. Mem.,
Chief Engineer, Cincinnati, Hamilton and Dayton Ry., Carew Bldg., Cincinnati, Ohio.

WILSON, J. F., Act. Mem.,
Chief Clerk, Engineer Department, Board of Trustees, Commissioners of Water Works, City Hall, Cincinnati, Ohio.

WILSON, WM. A., Assoc. Mem.,
Wilson & Strack, Contractors, Ninth and Plum streets, Cincinnati, Ohio.

WRAMPELMEIER, F. W., Act. Mem.,
Chicago and Alton R. R., Joliet, Ill.

WULFF, A. G., Act. Mem.,
Civil Engineer, 459 Riddle Rd., Cincinnati, Ohio.

Association of Engineering Societies.

Vol. XXIV. FEBRUARY, 1900. No. 2.

PROCEEDINGS.

Engineers' Club of St. Louis.

502D MEETING, FEBRUARY 7, 1900.—Meeting was called to order at 8.20 P.M.; President Chaplin presiding. Twenty-three members and nine visitors were present. The minutes of the 501st meeting were read and approved. The minutes of the 286th meeting of the Executive Committee were read.

The application of Mr. Charles F. Sturtevant having been recommended by the Executive Committee, he was balloted for and declared elected. Mr. James Adkins, Jr., was proposed for membership.

Communications received from the Secretary of the Washington University Alumni Association, and Congressmen Bartholdt and Joy, were read. The offer of Mr. Robert Moore to present the Club with a framed crayon portrait of his father, a charter member and former President of the Club, was accepted and the Secretary requested to tender thanks in behalf of the Club.

It was moved and carried to spread on the records the memoirs and minutes of the Polytechnic Society, the forerunner of our Engineers' Club.

The paper of the evening, on "Condensing Apparatus," was presented by Mr. W. H. Reeves, manager of Henry R. Worthington, St. Louis. The two types of condensers, surface and jet, were fully described and illustrated by slides. The advantages of each type and its application to given conditions were discussed. Where natural water supply is not available cooling towers are used, through which water is circulated and cooled, after which it is returned to condenser. The cooling surface is generally made of tile, but where the cooling towers are placed on the roof it is essential to reduce their weight, in which case successive layers of hollow tin tubes are used, 18 inches long and about 3 inches to 4 inches in diameter.

It was claimed that by the use of compound engines, running condensing, a resulting steam economy of 30 per cent. to 40 per cent. was effected over single cylinder non-condensing engines. Dr. Charles E. Emery's figures showed 25 per cent. gained in running a compound engine condensing over the same operating non-condensing.

By the use of a self-cooling condenser, which implies a "Cooling Tower,"

the advantages of condensation can be added to that of a central location for a power plant, where a natural water supply is not available.

The discussion was actively participated in by Messrs. Bryan, Flad, Freeman, Matlack, Ludington and Bausch.

Prof. F. E. Nipher gave a brief account of the latest development of his wind pressure apparatus. By its means, simultaneous measurements may be taken of the velocity of the wind and the wind pressure. The direction of the wind may also be accurately determined at any instant. Interesting diagrams were drawn illustrating the variation of wind pressures due to the velocity of the wind.

Meeting adjourned. F. E. BAUSCH, *Secretary.*

503D MEETING, FEBRUARY 21, 1900.—The meeting was called to order at 8.25 P.M.; Vice-President E. J. Spencer presiding. The minutes of the 502d meeting were read and approved. The minutes of the 287th meeting of the Executive Committee were read.

The application of Mr. James Adkins, Jr. having been recommended by the Executive Committee, he was balloted for and declared elected.

The subject of the evening was presented by Mr. Albert Borden. It was a "Discussion of Some Unusual Constructions in Structural Engineering." Mr. Borden gave a number of demonstrations on the blackboard, of how certain problems he had met with were solved in a manner original with him. Among these problems were the erection of a wooden tower, showing how simply it could be constructed, provided the corner blocks were made in a definite manner, and all side bracings were laid off at an angle of forty-five degrees. A novel manner of arranging a footing for iron columns, which were inserted into an old building whose front was altered was also described and demonstrated. A problem of unique character was presented in the shape of a cylinder 30 feet in diameter and 100 feet long, intended to be revolved by suitable gearing and motive power. The structural bracing was designed in quadrants of a circle, and a spiral track on the inside served to carry cars longitudinally when the cylinder was revolved. A number of interesting problems arose in calculating the stresses of the members in this iron construction. The discussion of the various problems was participated in by Messrs. Ockerson, Maltby, Van Ornum, Hazzard and Boyd.

Meeting adjourned.

F. E. BAUSCH, *Secretary.*

Technical Society of the Pacific Coast.

DIRECTORS' MEETING, SAN FRANCISCO, CAL., JANUARY 26, 1900.—Called to order by Vice-President Falkenau. The Secretary read the names of the officers and directors elected at the annual meeting, as follows:

President—G. W. Percy.

Vice-President—Louis Falkenau.

Secretary—Otto von Geldern.

Treasurer—E. T. Schild.

Directors—Hermann Barth, T. W. Brooks, A. E. Chodzko, E. F. Haas, S. C. Irving.

The following committees were then appointed by the Chair:

Messrs. Chodzko and Brooks, who, together with the President and Vice-President of the Society, form the Executive Council.

Finance Committee—Messrs. Barth, Haas, Irving.

Managers of the Board of the Association of Engineering Societies—D. C. Henny and Otto von Geldern.

The time for the meeting of the Board of Directors was fixed for the third Saturday of each month at 4 P.M.

Adjourned. OTTO VON GELDERN, *Secretary.*

REGULAR MEETING, SAN FRANCISCO, FEBRUARY 2, 1900.—Called to order at 8.30 P.M. by Vice-President Falkenau.

The minutes of the last regular meeting and of the annual meeting were read and approved.

Application for membership of J. H. G. Wolf, junior engineer, U. S. Engineer Department, proposed by Major C. E. L. B. Davis, Herbert Vischer and Otto von Geldern, was read and referred to the Board of Directors.

A general discussion then followed on the subject of "Dry Docks" and on "The Flow of Artesian Wells," in which the members present participated.

Adjourned.

OTTO VON GELDERN, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., JANUARY 24, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M.; Vice-President Alexis H. French in the chair. Seventy-eight members and visitors present.

The records of the last regular meeting and of the special meeting of January 12 were read and approved.

Mr. Addison D. Nickerson was elected a member of the Society.

On motion of Mr. Metcalf, the thanks of the Society were voted to the Boston Elevated Railway Company for courtesies extended to the members of the Society on the occasion of the visit to elevated railway work now under construction on January 10, 1900.

On motion of Mr. R. S. Hale, the Chairman was requested to appoint a committee to report to the meeting the names of five members to serve as a committee to nominate officers. On motion of Mr. Barnes it was voted to make this preliminary committee consist of three members. The Chair appointed Messrs. R. S. Hale, H. D. Woods and George Bowers as the committee. Later in the evening this committee reported as a Nominating Committee Messrs. George F. Swain, Henry S. Adams, Thomas Aspinwall, Edgar S. Dorr and Francis W. Dean. The report was accepted, and the members named were chosen as the Nominating Committee.

The Secretary read a memoir of Sumner Hollingsworth, a member of the Society, prepared by Messrs. John R. Freeman and Charles T. Main; also, a memoir of William S. Whitwell, an honorary member, and one of the founders of the Society, prepared by Messrs. Francis Blake and Ernest W. Bowditch.

The Chair announced that a special meeting of the Society would be held on February 1, at which an opportunity would be given to meet the members of the Canadian Society of Civil Engineers.

Prof. Leonard F. Kinnicutt, of the Worcester Polytechnic Institute, was then introduced, and read an exceedingly interesting and valuable paper entitled "Recent Experiments on the Bacterial Treatment of Sewage, with an Account of the Work Done at Manchester during the Past Year."

After passing a vote of thanks to Professor Kinnicutt, the Society adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., FEBRUARY 1, 1900.—A special meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 8.30 o'clock P.M.

President C. Frank Allen called the meeting to order and extended a most cordial welcome on behalf of the Society to the members of the Canadian Society of Civil Engineers who were present.

Mr. Frederic P. Stearns then gave a description of the Metropolitan Water System, now under construction. The description was very fully illustrated by stereopticon views.

Prof. Henry T. Bovey, President of the Canadian Society of Civil Engineers, expressed the thanks of the members of that Society for the attention which they had received from the members of the Boston Society, and their appreciation of the arrangements which had been made for their entertainment during their visit at Boston. Mr. John Kennedy, a Past-President of the Canadian Society, followed and seconded most heartily the kindly expressions of Professor Bovey.

The meeting then adjourned to the Society's library and reading room, where an opportunity was given for a social hour, during which refreshments were served in an adjoining room.

The attendance of members and guests at the meeting was one hundred and thirty-five.

Adjourned. S. E. TINKHAM, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., FEBRUARY 5, 1900.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M.

Present, fourteen members and four visitors; President Powell in the chair.

Minutes of previous meeting read and approved.

Auditors' report read and accepted.

Mr. C. F. Loweth read a paper on "Moving Horizontally a 361-foot Railroad Bridge Span with Oak Wedges."

Mr. A. W. Münster described his experience in raising heavy weights with wedges. To cite one case: a steel tower 130 feet high supporting deck spans and resting on masonry pedestals, two of which had settled. To plumb the tower thin steel wedges, forty-two to a pedestal, were alternately driven and shimmed by eighths of an inch, thus lifting about 300 tons an inch and a half without damage to bridge, masonry or wedges. The wedges were 18 inches long, 3½ inches wide, rising ⅜ inch in 12 inches and were forged under steam hammer from locomotive springs taken from scrap heap.

C. L. ANNAN, *Secretary.*

Engineers' Club of Cincinnati.

112TH REGULAR MEETING, CINCINNATI, OHIO, FEBRUARY 15, 1900.

Dinner was served at 6.15 P.M.

The regular meeting was called to order at 7.15 P.M.; with President Punshon in the chair, and thirteen members present.

Minutes of the meeting of January 18 were read and approved.

Mr. Wm. C. Green read the paper for the evening on "Steam Heating at and below the Pressure of the Atmosphere."

On motion, adjourned.

J. F. WILSON, *Secretary.*

Errata.

In the list of members of the Associated Societies, published in the JOURNAL OF THE ASSOCIATION for January, 1900, the name of Prof. Alexander Ziwet was wrongly included in the list of the Boston Society of Civil Engineers instead of that of the Detroit Engineering Society.

Numerous errors having been discovered in the list of the Engineers' Society of Western New York, that list is herewith given in corrected form.

Engineers' Society of Western New York.

Babcock, C. E. P.,
Asst. Engineer, Department of Public Works,
13 City Hall, Buffalo, N. Y.

Bardol, F. V. E.,
Chief Engineer, Department Public Works,
13 City Hall, Buffalo, N. Y.

Bassett, Geo. B.,
Manager Buffalo Meter Co.,
363 Washington street, Buffalo, N. Y.

Brackenridge, W. A.,
Engineer Cataract Construction Co., Niagara Falls, N. Y.

Buttolph, H. T.,
Assistant Chief Engineer, Department Public Works,
13 City Hall, Buffalo, N. Y.

Carlton, Newcomb,
Director of Works, Pan-American Exposition,
Service Bldg., Buffalo, N. Y.

Cornell, Douglas,
Structural Engineer, Bureau of Buildings,
Municipal Bldg., Buffalo, N. Y.

Diehl, Geo. C.,
County Engineer, Erie County,
836 Ellicott Square, Buffalo, N. Y.

Ellsworth, John F.,
Cor. Franklin and Eagle streets, Buffalo, N. Y.

Fell, Chas. F.,
Assistant Engineer, Department Public Works,
13 City Hall, Buffalo, N. Y.

Fell, Geo. E.,
Doctor of Medicine, 97 Prospect ave., Buffalo, N. Y.

Fields, S. J.,
Chief Engineer, Pan-American Exposition,
Service Bldg., Buffalo, N. Y.

Früauff, Geo. Ph.,
Leveler, Department Public Works, 13 City Hall, Buffalo, N. Y.

Gaskin, E. F.,
Superintendent Union Dry Dock Co.,
Ganson street, Buffalo, N. Y.

Gorham, Marvine,
Buffalo Bolt and Nut Works, 250 Elmwood ave., Buffalo, N. Y.

Guthrie, E. B.,
Chief Engineer Grade Crossing Commission,
436 Ellicott Square, Buffalo, N. Y.

Hammond, Richard,
President Lake Erie Eng. Works, Buffalo, N. Y.

Harrower, H. C.,
Iron and Steel Contractor, 35 Court street, Buffalo, N. Y.

Haven, W. A.,
Inspecting Engineer, Erie Railroad,
E. R. R. Depot, Buffalo, N. Y.

Hill, Prof. H. M.,
City Chemist, University of Buffalo, Buffalo, N. Y.

HOFFMAN, A. W.,
Assistant Engineer, Department Public Works,
13 City Hall, Buffalo, N. Y.

HOUCK, WM. C.,
Member of firm Buffalo Structural Steel Work,
97 High street, Buffalo, N. Y.

HUBBELL, GEO. S.,
Corps of Engrs., U. S. A., Adjuntas, Porto Rico, U. S.

JOHNSON, WALLACE C.,
Engineer, Niagara Falls Hydraulic Co., Niagara Falls, N. Y.

KNAPP, L. H.,
Assistant Superintendent and Engineer, Bureau of Water,
Municipal Bldg., Buffalo, N. Y.

KNIGHTON, JOHN A.,
Assistant Engineer, Grade Crossing Commission,
436 Ellicott Square, Buffalo, N. Y.

LUFKIN, E. C.,
Manager Snow Steam Pump Works,
102 Anderson Pl., Buffalo, N. Y.

MARCH, HARRY J.,
Assistant Engineer, Department Public Works,
13 City Hall, Buffalo, N. Y.

MEYER, CARL,
Member of firm Buffalo Bridge Works,
P. O. Drawer 170, Buffalo, N. Y.

McCULLOH, WALTER,
Private Practice, Crick Block, Niagara Falls, N. Y.

MORSE, CHAS. M.,
Mechanical Engineer,
Erie Co. Savings Bank Bldg., Buffalo, N. Y.

POWELL, S. W.,
Mechanical Engineer, 679 Auburn ave., Buffalo, N. Y.

RATHMAN, L. H.,
Leveler, Department Public Works, 13 City Hall, Buffalo, N. Y.

RAFTER, GEO. W.,
Consulting Engineer, 403 Bronson ave., Rochester, N. Y.

RICKER, GEO. A.,
Private practice, 702 Ellicott Square, Buffalo, N. Y.

ROBERTS, GEO. T.,
Assistant Engineer, Department Public Works,
13 City Hall, Buffalo, N. Y.

ROCKWOOD, A. J.,
Division Engineer, New York State Canals, Rochester, N. Y.

SMITH, T. GUILFORD,
Vice-President, New York Car Wheel Works,
9 German Insurance Bldg., Buffalo, N. Y.

SORNBERGER, E. C.,
Snow Steam Pump Works, 208 Lancaster ave., Buffalo, N. Y.

SPEYER, F. N.,
Assistant Engineer, Grade Crossing Commission,
436 Ellicott Square, Buffalo, N. Y.

SYMONS, THOS. W., Hon. Mem.,
Major of Engineers U. S. A., Morgan Bldg , Buffalo, N. Y.

TEIPER, CASPER,
Member of firm Buffalo Structural Steel Works, Buffalo, N. Y.

TRESISE, F. J.,
Draftsman, Department Public Works, 13 City Hall, Buffalo, N. Y.

TUTTON, C. H.,
Engineer, Grattan & Jennings, foot of Main street, Buffalo, N. Y.

VANDER HOEK, J.,
Division Engineer, Lehigh Valley Railroad,
L. V. R. R. Depot, Buffalo, N. Y.

WHITFORD, O. F.,
Private practice, 79 Woodlawn ave., Buffalo, N. Y.

Association of Engineering Societies.

Vol. XXIV. MARCH, 1900. No. 3.

PROCEEDINGS.

Montana Society of Engineers.

The 13th annual meeting of the Montana Society of Engineers was held in the city of Bozeman, Mont., on January 12 and 13, 1900. On Friday morning, the 12th, the members left by private conveyance for the visit to the coal mines and washer of Johnston & McCarthy, located at Chestnut, about twelve miles from Bozeman. Arriving about noon, the members sat down to a most bountiful dinner especially prepared for them, after which an inspection of the property was made under the guidance of the foreman in charge.

The party next proceeded to the United States Government Fish Hatchery, located in Bridger Canyon, about three and one-half miles from Bozeman. Dr. James A. Henshall, in charge, greeted the party upon arrival, and very pleasantly entertained and instructed them, giving detailed descriptions of the working and results for the past year.

The grounds comprise about seventy acres, and about twenty-five acres are in use for ponds and buildings. The hatchery building, which is 50 by 80 feet, has thirty-five hatching troughs, 300 hatching trays, with a capacity of 1,500,000 fish eggs. Last season 750,000 fish were reared and afterwards distributed in the streams of Montana, Idaho, Oregon and Washington.

On the return trip, the party stopped at the flouring mills of Nelson Story & Co. These are the largest and best equipped of any in the State, having a capacity of storing 400,000 bushels of grain, grinding 300 barrels of flour a day, and storage capacity for 50,000 sacks of flour. After the inspection of the mill including the water wheel, which furnishes the power, the party continued homeward, arriving at Bozeman at 6 P.M.

At 8 o'clock, Friday evening, a special meeting of the Society was held in the dining room of the Hotel Bozeman, for the purpose of hearing read the paper on the "Reconstruction of the Big Hole Dam" by Jos. H. Harper, of Butte, the engineer in charge. After the reading and discussion of the paper the meeting resolved itself into a smoker and social session, which lasted till about midnight.

At 9.30 A.M., on Saturday, the street car left the hotel and conveyed the members to the Montana State College grounds. The campus contains over thirty acres and is situated on the highest ground in the city, giving a magnificent view of the whole Gallatin Valley.

Adjoining the college campus is the experimental farm of 160 acres of the best land in the valley. The members first visited the main building, containing in the basement the domestic science rooms and several class rooms. On the first floor is the well-stocked library and reading room, besides offices and class rooms; on the second floor the business department occupies half the space, with a fully equipped business college, while the other half is occupied by the art department. This department was awarded a medal for its exhibit at the Omaha Exposition. On the third floor are the assembly room, drafting room and other class rooms.

Next the chemical and physical science building was visited, where well-lighted rooms were found, with finely equipped lecture rooms and laboratories for qualitive and quantitive analysis, mineralogy, preparatory and advanced physics, and assaying, besides a geological museum and research laboratory. The equipment of these laboratories seemed to be everything that could be desired.

The next place of interest was the shop building, where about twenty-five students were busy in various lines of wood and ironwork. The equipment in the way of wood and ironworking machinery covers everything in the line of standard shop machinery. The forge shop, with all the piping underground, was a model of neatness, and though ten fires were in use the air was entirely free from smoke or gas. From here they went to the engineering laboratory, which probably contains the finest outfit of testing machinery to be found west of the Mississippi River, covering the lines of steam and electrical engineering. Two machines of special interest were a pair of multipolar dynamos which could furnish either direct or single-phase, two-phase or three-phase alternating currents.

The machine of greatest interest to the members, however, was a Riehlé standard testing machine of 100,000 pounds capacity, having automatic and autographic attachments. For the benefit of the visitors a specimen of wrought iron was broken, giving them a chance to see how the machine autographically constructs its own stress-strain curve.

Another machine of interest was an Olsen Torsion Tester of 50,000 inch-pounds capacity, which was also in operation at that time. The last building visited was the experimental station containing the botanical and zoological laboratories, whose equipment was well up to what was seen elsewhere. In the basement of this building, in the office of the irrigation engineer, the visitors had a chance to inspect some of the latest and finest patterns of water measuring instruments, besides various patterns of standard surveying instruments.

The annual meeting proper, held in the Odd Fellows' Hall, Bozeman, Montana, Saturday afternoon, January 13, 1900, was called to order at 2.30 P.M., by President Eugene Carroll, of Butte, Montana.

Mr. Robert A. McArthur, of Butte, was appointed by the President to act as Secretary of the meeting.

The following members were in attendance at the meeting:

Samuel Barker, Jr., Francis W. Blackford, Winfield J. Flood, Joseph H. Harper, J. S. B. Hollinshead, Albert Koberle, Malcolm L. Macdonald, Frank L. Sizer, Richard R. Vail, Charles D. Vail, Eugene Carroll, William H. Harrison and Robert A. McArthur, all of Butte; Ernest W. King, of Gilt Edge; James S. Keerl, of Helena; Benj. D. Whitten, of Great Falls; E. C. Kinney, of Manhattan; William H. Williams and Edmund B. McCormick,

of Bozeman. Also the following guests: C. W. Payne, E. H. Burlingame, A. E. Hobart and J. H. Trerise, of Butte, and President Jas. Reid and Professor Fortier, of the Agricultural College, Bozeman.

The minutes of the last meeting were read, and, on motion, adopted. The next order of business was the reading of the reports of the Secretary and Treasurer for the past year, as follows:

Report of the Secretary.

January 13, 1900.

To the President and Members of the Montana Society of Engineers:

Gentlemen:—I have the honor to submit my report as Secretary of the Montana Society of Engineers from January 14, 1899, to January 13, 1900:

Amount in treasury on January 14, 1899	$42.31
Total amount deposited with F. J. Smith, Treasurer, from January 14, 1899, to January 13, 1900 (as per receipts herewith attached), Nos. 1 to 13, inclusive	969.00
Total	$1,011.31
Total amount expended during the year from January 14, 1899, to January 13, 1900, as per orders Nos. 1 to 31, inclusive	784.30
Balance in treasury on January 13, 1900	$227.01
Cash on hand from recent collections not deposited in treasury	128.00
Total amount of cash on January 13, 1900	$355.01

All bills against the Society have been paid and the Society has no outstanding accounts except what there may be from expenses of 13th annual meeting.

MEMBERSHIP OF THE SOCIETY.

	Jan. 14. 1899.	Jan. 13, 1900.
Honorary members	4	4
Active members	114	117
Associate members	20	21
Total	138	142

The Society has lost one member by death during the past year. Henry C. Relf was drowned in the Clarks fork of the Columbia River on June 9, 1899.

Two years ago the Society established the precedent of publishing the proceedings of the annual meetings. These are reprints from the Journal of the Association of Engineering Societies. 250 copies were published of the 12th annual meeting, including the list of members. The list of members was practically new matter and added, as near as I can estimate from bill for said publication, $16.00 to same. The Society now receives about 25 exchanges, and the proceeding of our annual meetings is about all we have to offer in return. This year the January number of the Journal will contain list of members in full, including professions or occupations of members, and reprints can be had at reasonable rates. These could be ordered several months later than the issue of the Journal and the reprints could be revised to date, including the new additions to the Society as well as changes in address of present members. The changes in the membership of our Society is so great that the list of membership should be published frequently.

Very respectfully,

A. S. Hovey, *Secretary.*

The report was adopted as read, and, on motion, was referred to the Board of Trustees for auditing.

TREASURER'S REPORT M. S. E.

By amount received from J. S. Keerl, ex-Treasurer................		$42.31
" " " " A. S. Hovey, Sec'y (receipt Nos. 1 to 13).		969.00
To expenditures (order Nos. 1 to 31) as per vouchers herewith transmitted	$784.30	
By balance in treasury	227.01	
Totals	$1,011.31	$1,011.31

Respectfully submitted,

FORREST J. SMITH, *Treasurer.*

This report was adopted as read, and referred to Board of Trustees for auditing.

Messrs. Koberle and Hollinshead were appointed by the Chair, as tellers, to canvass the ballots on election to membership, and also election of officers for the ensuing year.

The report of Mr. James S. Keerl, member of the Board of Managers of the Association of Engineering Societies, was then read. and, on motion, adopted.

Applications for membership in the Society were read from the following gentlemen: Geo. W. Wilson, David W. Hardenbrook, Azelle E. Hobart, Benj. R. Putnam, Jerry Rourke, John B. Leggat, Josiah H. Trerise, William E. Sanders, Geo. W. Tower, Jr., Eugene C. Sickles and Walter W. Wishon. The Secretary was instructed to send out the usual letter ballots to the members, the same to be canvassed at the next regular meeting.

The tellers appointed to canvass the ballots on membership reported as follows: That Edmund B. McCormick, of Bozeman, had received thirty-two votes, all in the affirmative, upon which the Chair declared him to be duly elected to membership.

On the balloting for officers, the tellers reported as follows:

For President—Francis W. Blackford, of Butte, thirty votes.

For First Vice-President—Albert S. Hovey, of Helena, thirty votes.

For Second Vice-President—William H. Williams, of Bozeman, thirty votes.

For Secretary and Librarian—Robert A. McArthur, of Butte, thirty votes.

For Treasurer and member of the Board of Managers of the Association of Engineering Societies—Joseph H. Harper, of Butte, 30 votes; James S. Keerl, of Helena, one vote.

For Trustee (for three years)—Geo. E. Moulthrop, of Butte, thirty votes.

On motion, Mr. Harper's election was made unanimous, and the Chair declared the other gentlemen, having received all the votes cast, to be the duly elected officers for the ensuing year.

Mr. Harper and Mr. Sizer were appointed a committee to escort President Blackford to the chair.

Upon assuming the chair, President Blackford spoke as follows:

"I thank you sincerely for the honor you have conferred upon me by the office of President for the ensuing year. The respect and good will of my professional brethren has always been held in high esteem, and the honor

conferred is appreciated accordingly. There is no mandatory provision relative to an address by the incoming President as there is of the one retiring. Still, I desire to say a few words upon the subject of society work.

"Our Constitution says: 'Section 2. Its object shall be the advancement of engineering, and the interests of the profession.

"'Section 3. Among the means to be employed shall be periodical meetings for the reading and discussion of scientific papers and matters of scientific and practical interest, and the cultivation of professional and social intercourse among the members; the collection of a library, and the publication of such parts of the transactions as may be deemed expedient.'

"These results can be accomplished only by a proper understanding of our profession and by earnest and intelligent work by its members. Skilled workmen and engineers date from the earliest civilization, and they have been the pioneers of progress and enterprise from the earliest times, but not till recently, even within the present century now drawing to a close, has engineering been recognized as one of the learned professions, and any one at all in touch with the times realizes that its recognition is becoming more and more general, and its influence, because of the great things accomplished, is becoming greater.

"The tendency of the present time is to educate by an engineering course, even though the recipient of such education expects to engage in business pursuits. I am informed that the graduates of the college engineering courses in America number quite as many as the graduates in medicine.

"The Institution of Civil Engineers defines engineering as 'The art of directing the great sources of power in nature for the use and convenience of man.' What more laudable purpose could any occupation have; there is in theory no destruction, no success depending upon some other man's failure, no tearing down, but all building up with nature and materials, resulting in the reduction of exhausting toil and general good to mankind. Engineering is in an eminent degree a productive employment, and one in which we should all feel a pride, a pride for its motives and a pride for its accomplishments.

"An engineer, in the sense of the term as understood by engineers themselves, is not only a skilled workman, but a designer as well; he should understand the theory back of his employment, and the engineer of to-day must be an educated man, for in no profession is education more necessary, and unless he possesses a broad and comprehensive general and theoretical knowledge he will be classed as a workman rather than as a professional man. While he cannot be a specialist in many branches, he should have sufficient knowledge to understand, in a general way, all special branches.

"It is generally believed that there is no more practical way of adding to our store of knowledge, both theoretical and practical, than by the preparation and discussion of professional papers. We have, as examples, all the engineering work which has been done before, and that which is now doing, and the research which is necessary in the preparation of papers, and the discussion elicited thereby will certainly increase the knowledge of all concerned.

"Discussions which are brought out by a paper are often more valuable than the paper itself, as they stimulate the interchange of opinions and experiences, and result in a general benefit. Our Society is growing in numbers and has upon its membership roll men prominent in several branches of engineering and scientific pursuits, and we trust its influence is widening,

and that it may result in much good to the Society and its individual members. The good it may do, however, depends on the energy and intelligent interest displayed by its members, and such interest can best be shown by papers and discussions upon interesting subjects. There are now about one hundred and twenty members, other than the honorary and associate members, so that we could have a paper every meeting, if each member wrote one every ten years, which should be time enough, and with reasonable diligence each meeting should be enlivened by a paper and discussions. I would earnestly recommend that members make efforts in this direction.

"The Society has now moved its headquarters to Butte, which is the residence of most of its officers and about forty members, quite enough to insure a good attendance at monthly meetings. A suitable room for our library and meeting place should be provided by the trustees without delay, and it should be properly furnished, so that members of the Society could use it at all times in the day or evening.

"I would suggest that the room be supplied with some of the leading engineering papers and magazines, and with Society stationery, and that the furniture be comfortable and the surroundings pleasant. Those who feel so disposed could spend their spare time there both pleasantly and profitably and such a place would promote that social intercourse among members which is so desirable in society work."

Mr. W. Williams, Second Vice-President, was then called upon for a speech, and responded as follows:

"I thank you for the honor of electing me to this position. I feel heartily in sympathy with the words of the President, and I shall do all I can to increase the usefulness of this Society."

Mr. Robert A. McArthur, Secretary, was asked to make a few remarks, and answered as follows:

"Mr. President and fellow-members of the Montana Society of Engineers, the incoming Secretary is not supposed to make very much of a speech. He merely says thank you, and sits down. I thank you for the honor you have done me, and ask your forbearance, and I shall fulfill the duties of my office for the coming year to the best of my ability."

The President introduced Mr. Harper, Treasurer-elect, who thanked the Society for the honor of his election.

The President introduced Mr. E. B. McCormick, member-elect, who said: "I thank you all for the honor of my election, and I think I will take the full length of that ten years to make a speech."

There being no unfinished business, the Society proceeded to the order of new business.

Mr. Hollinshead.—I think it would be in order to pass a vote of thanks to Mr. Henshall at the Fish Hatchery, and to Messrs. Johnson & McCarty, at the Chestnut Mines, and the officers connected with the company, to the officers connected with the college and its professors, for what they have done to make this such a successful meeting, and that the Secretary be instructed to send our thanks in writing.

Mr. Williams.—I would add the name of the Bozeman Street Railway, Nelson Story Milling Company, and (by Mr. Carroll) the members of the Committee on Arrangements, and also Mr. Mueller.

Mr. Carroll.—Two of the officers of the Society are entitled to the thanks of the Society at this time. I refer to ex-Secretary, Mr. A. S. Hovey,

who has been Secretary for three years. He has given us a great deal of his time, and has kept the affairs of the Society in good condition during his term of office, and he is particularly deserving of mention. The other officer I refer to is Mr. J. S. Keerl, to whom the success of the JOURNAL OF THE ASSOCIATION is very greatly due. His office is one that we do not see the benefits of so readily as we do those derived from the office of Secretary. I therefore move that the vote of thanks be extended to Mr. Keerl and Mr. Hovey in addition to the rest.

Upon being seconded by several members, the President put the motion to the house and it was carried unanimously.

The Society then proceeded to the program arranged for the afternoon, the Chairman deciding that the paper of the retiring President should have precedence, whereupon Mr. Eugene Carroll, of Butte, delivered his retiring address, the same being a summary of engineering progress in Montana during the past year.

MR. SIZER.—Mr. President, I move for a vote of thanks of this Society to Mr. Carroll for this unusually able and interesting paper, and later, after the reading of the other paper, I will move for the publication of both papers. Motion carried.

Next came the paper, entitled "The Flow of Water in Ditches and Canals," by Professor Fortier, of the Montana College of Agriculture and Mechanic Arts. A vote of thanks was tendered Professor Fortier for his able paper, and the Society proceeded to the next order of business.

MR. SIZER.—As a member of the Committee on Arrangements, I desire that a tax of $3.50 be levied upon those members in attendance, to cover the cost of the banquet and some incidental expenses.

A motion was made to that effect and duly carried.

MR. CARROLL.—There are many things requiring change in the Constitution. In the change of headquarters to Butte, the word "Helena" is to be changed, and a general revision of the Constitution ought to be made. I suggest that we make a motion that a Committee be appointed, with the President and Secretary as members, to take up the matter, or possibly they alone might do so and report to the Society what changes ought to be made before the new Constitutions are printed. Mr. Hovey and myself decided that it would be best to leave it to the new officers. There are no copies of the Constitution left. I would state that many of the Societies, in publishing their Constitutions, include it with their annual proceedings. The question is, however, whether the Society would want more copies of the Constitution than of the proceedings.

THE PRESIDENT.—It would take some time to revise the Constitution, and I would advise publishing it in the old form.

After some discussion, it was finally decided that the matter should be left to the President and Secretary to report any desirable changes to the next meeting.

MR. CARROLL.—I move that the Secretary be instructed to extend our thanks to the Great Northern Railroad Company, Northern Pacific Railroad Company, Butte, Anaconda and Pacific Railroad Company and the Oregon Short Line for the courtesies extended to the Society in the reduction of the regular rates for the annual meetings. Motion carried.

Upon motion by Mr. King, seconded by Mr. Keerl, the Society adjourned for the session, to meet at 8 o'clock in the Hotel Bozeman, to partake of the annual banquet.

The banquet commenced at 9 P.M., with about sixty-five members and guests present, the latter including about twenty-five ladies.

Music was furnished by the Bozeman orchestra, and several of the ladies and gentlemen present favored the company with vocal selections. The following toasts were given, Mr. Eugene Carroll acting as toastmaster:

"Our Convention City," Dr. Jas. Reid, President of Agricultural College.

"The Pioneers of Travel, the Railway Location Engineers," by Francis W. Blackford.

"The Forerunner of Wealth; the Prospector," by Jos. H. Harper.

"The Life Blood of a City—Its Water Supply," by Chas. D. Vail.

"The Out of Sight Man—The Mining Engineer," by Albert Koberle.

"Dams and Damsels," by James S. Keerl.

"Why I Did Not Become an Engineer," by Gen. L. S. Willson.

Regular Meeting, Butte, Montana, March 10, 1900.—The meeting was called to order by President F. W. Blackford, with the following members present: Patterson, Flood, Putnam, Harper, Barker, Dunshee, Carroll, R. R. Vail, Koberle, Zaschke, Page and McArthur. The minutes of the previous meeting were read and approved. Messrs. Flood and Barker were appointed tellers to canvass ballots on membership, and after a recess of five minutes reported that Mr. Horace V. Winchell had received all the votes cast and he was declared duly elected to membership.

A communication from Mr. Davies was read regarding the bill now before the Senate and House of Representatives, having to do with the mail rate on library books, and after discussion the Society indorsed the bill and the Secretary was instructed to write our Senators and Representative in behalf of the bill.

The following resolution introduced by Mr. Carroll, after discussion was unanimously adopted:

Resolved, That the President and Secretary are hereby instructed that each month they shall pick out the names of three members from a box containing a list of the members of the Society, thereupon the Secretary shall notify the said three members thus selected that they are called upon to furnish a paper or lead in a discussion at the next meeting of the Society, the said members to select their own subject and to notify the Secretary that he may announce it in the next notice of meeting sent out by him to the members of the Society.

An informal discussion on smokestacks now took place, and some of the members promised to bring data regarding the new self-supporting steel stacks recently erected in Butte and vicinity, whereupon President Blackford announced that the next meeting of the So 'ety will be devoted to a discussion of chimneys and smokestacks, and requested all the members to bring information on the subject. Adjourned.

Robert A. McArthur, *Secretary*.

Civil Engineers' Club of Cleveland.

THE annual meeting, March 13, attended by twenty-seven members and six visitors: Mr. Wm. H. Searles, Chairman *pro tem.*

Sixteen new members elected and six more proposed.

Mr. Aug. Mordecai reported that a reception by the Club would be held on the evening of March 29, at The Stillman. It was moved and carried that all members of the Associated Technical Clubs be invited on equal terms with members of the Civil Engineers' Club.

Reports of the Secretary, Treasurer and Programme Committee presented. The address of the retiring President, Col. Jared A. Smith, was read by the Secretary.

The following officers of the Club were elected:

President—Charles W. Hopkinson.

Vice-President—Charles H. Benjamin.

Secretary—Arthur A. Skeels.

Treasurer—John N. Coffin.

Librarian—Wm. E. Reed.

Directors—Edward A. Handy and Marius E. Rawson.

SECRETARY'S FINANCIAL REPORT FOR YEAR ENDING MARCH 1, 1900.

RECEIPTS.

Dues	$1,564.50
Entrance fees	70.00
Library subscriptions	165.00
Publications	133.70
Interest	33.25
	$1,966.45

EXPENDITURES.

Publications	$207.20
Printing	131.85
Social account	159.83
Stenographer	15.00
Postage and express	25.00
Room rent	636.00
Flowers	40.00
Members' certificates	5.50
Library supplies	39.73
Books	96.38
Furnishings	493.37
Case Library memberships	140.00
Salaries	150.00
	$2,139.96

BALANCES ON HAND.

Permanent Fund	$915.55
General Fund	311.84
Library Fund	173.74
	$1,401.13

ARTHUR A. SKEELS, *Secretary.*

Treasurer's Report.

RECEIPTS.

Balances from former Treasurer:		
Permanent Fund	$812.30	
General Fund	657.22	
Library Fund	105.12	
		$1,574.64
Received from Secretary on account of Permanent Fund	$70.00	
" " " " " General Fund	1,698.20	
" " bank, interest	33.25	
" " Librarian	165.00	
		1,966.45
		$3,541.09

DISBURSEMENTS.

Secretary's vouchers on account of General Fund	$2,043.58	
" " " " " Library "	96.38	
		2,139.96

BALANCES ON HAND.

Permanent Fund	$915.55	
General Fund	311.84	
Library Fund	173.74	
		1,401.13
		$3,541.09

John N. Coffin, *Treasurer.*

The semi-monthly meeting, March 27, attended by nineteen members and ten visitors; President C. W. Hopkinson in the chair.

No business transacted.

Mr. E. P. Roberts read a paper entitled "Some Problems in Electric Railway Design." Discussion taken part in by Messrs. Roberts, Wason, Palmer, Porter and Kingsley.

Annual reception and twentieth anniversary held at The Stillman, March 29. Present, about one hundred and fifty members and guests. Past-President Jared A. Smith and President Chas. W. Hopkinson, with their ladies, received from 8.30 to 10.00. Lunch, 10.00 to 10.45. Speeches were then made by Col. Jared A. Smith, toastmaster, and Messrs. F. C. Osborn, Wm. Garrett, J. N. Coffin, C. W. Wason, A. A. Skeels, C. S. Howe and C. W. Hopkinson. Dancing and cards, 12.00 to 2.00.

Arthur A. Skeels, *Secretary.*

Engineers' Club of St. Louis.

504th Meeting, March 7, 1900.—Meeting was called to order at 8.15 p.m.; Vice-President E. J. Spencer presiding. Sixteen members and nine visitors were present. The minutes of the 503d meeting were read and approved. The minutes of the 288th meeting of the Executive Committee were read.

The paper of the evening was on "Experiences in the Operation and Repair of the Mississippi River Hydraulic Dredges," by F. B. Maltby.

From July, 1898, to May, 1899, Mr. Maltby was in charge of dredging operations under the Mississippi River Commission, as superintendent of dredging. During this season the fleet consisted of five dredges, nine steamboats, five pile drivers, and the necessary barges, fuel boats, etc. The river below Cairo was divided into three districts, the first two having a length of about 100 miles, and the third extending below the second district down stream as far as dredging was necessary.

An interesting description was given of the operations necessary to open up a channel. One of the dredge boats in dredging a channel removed fifty-four logs varying from 8 to 50 inches in diameter, aggregating a length of over 1500 feet. In consequence of severe usage, accidents are of frequent occurrence.

An account was given of field tests made with the dredges for comparison with trial tests, made before acceptance of the boats from their builders. It was feared that test conditions were not of the same character as working conditions, the former being made by measuring the discharge deflected for a brief interval of time, less than a minute, into a measuring barge. The tests made proved very satisfactory. Figures were given of cost of operating the dredges. A number of diagrams and sketches were shown indicating the amount of wear on the main sand pumps, reference being made to one case where in the lower half of the casing, on the port side, a slit of about 18 inches long was worn entirely through. The linings of the pumps all show considerable wear at the end of the season, this wear largely reducing the efficiency of the pump. Investigation in this respect made in 1899 showed that with an increase of the original clearance between the runner blades and casing from ⅛ inch to ¾ inch, the efficiency was reduced 50 per cent.

Mr. Maltby also described a series of experiments made with the steamer "Mississippi," used as an inspection boat while not in service, with the Mississippi River Commission. The propelling wheel of the steamer is 22 feet in diameter, 20 feet long and has 20 buckets. Experiments were made with a view to increasing the speed of the boat. It was thought the wheel was afflicted with too many buckets. Accordingly various trials were made by reducing the wheel area, giving various results. A reduction of one-half the area increased the speed 0.2 of a mile per hour, with an expenditure of 10 per cent. more power. The conclusion reached was that an improvement could be made by rebuilding the wheel, using only eighteen or nineteen arms, but this would have been impracticable. The discussion was participated in by Messrs. Colby, Bryan, Schwedtman and Bausch.

The President appointed a temporary committee for reception and lunch.

Adjourned.

F. E. Bausch, *Secretary.*

505th Meeting, March 21, 1900.—The meeting was called to order at 8.20 p.m.; President W. S. Chaplin presiding. Forty-one members and four visitors were present. The minutes of the 504th meeting were read and approved. The minutes of the 289th meeting of the Executive Committee were read. The application for membership of E. C. Angell was presented to the Club and referred to the Executive Committee for approval. A motion was made and carried that the President appoint a committee of three to report upon the feasibility and plan for awarding an annual prize for the best paper written by a member of the Engineers'

Club on an engineering subject. The Chair appointed B. H. Colby, J. H. Kinealy and W. A. Layman to serve on this committee. The following standing committees for the year were also appointed by the Chair: Committee on Monument to James B. Eads—Robt. Moore, Julius Pitzman and J. A. Ockerson; on Smoke Prevention—Geo. B. Leighton, Robt. Moore, Edw. Flad, W. H. Bryan and J. A. Vail; on Entertainment—E. E. Wall, A. L. Johnson and Wm. G. Brenneke.

The paper of the evening was on "City Lighting: Past, Present and Future," by Robt. E. McMath, President Board of Public Improvements. An historical review of the subject was given dating from some time in the 60's, when the city was lit by gas under a franchise. As early as 1863 municipal ownership of an illuminating plant had been discussed, but nothing came of it. Under the old cortract it was thought that the franchise authorizing the gas company to do business in St. Louis conveyed to the city the right to acquire the plant at the end of the contract. In later years the city tried to obtain possession of the plant of the St. Louis Gas Company, but was unsuccessful after long litigation.

In 1888 the subject of a new lighting contract was taken up by the Municipal Assembly. A joint committee from the Council and House of Delegates recommended the erecting of a lighting plant by the city, and negotiations were opened with the gas company with a view to purchasing or leasing its plant. These negotiations proved unsatisfactory and the project was given up. Then the Assembly passed two ordinances,—one calling for the illumination of the city by gas, the other by electricity. The latter ordinance was held up for some months in the House of Delegates, but it eventually passed. By its terms the Board of Public Improvements was given ten days' time in which to draw up specifications for lighting by electricity and to advertise for bids. The board was equal to the task, and the result was the award of a contract to the Missouri-Edison Electric Co. for lighting the city's streets and alleys for a term of ten years from 1890. Mr. McMath spoke at considerable length on the trouble which the Board of Public Improvements experienced in securing the passage of an ordinance authorizing a new lighting contract. The first ordinance, drawn in 1896, was passed successfully, but the companies refused to bid under it, owing to the severity of the conditions imposed. Another ordinance placing gas and electricity into competition was passed, but was attacked by the City Counselor and pronounced invalid. Thereafter ordinance after ordinance was drawn up by the board, only to suffer defeat in the Council on various pretexts. Finally public opinion was aroused and action was forced upon the city legislators.

Under the ordinances passed by virtue of the taxpayers' moral suasion, a temporary contract has been let. The Board of Public Improvements took up the question of lighting the city with gas and electricity, and to this end sent an ordinance to the Municipal Assembly which was duly passed. The ordinance divided the city into two districts, the resident portion, which included approximately that part of the city west of Jefferson avenue, south of Chouteau avenue and north of Cass avenue to be lighted by a refractory mantle, made incandescent by a hydrocarbon gas; the other part of the city, comprising the business district, to be lit by electricity. The contracts for both kinds of lighting have been let, the mantle lamp to the Kern Incandescent Gas Light Company, of New York, and the arc lamp to the Seckner Contracting Company, of Chicago.

Mr. McMath declared that the next lighting contract would not have such a difficult road to travel, unless the present ordinances were repealed. The discussion was participated in by Messrs. Holman, Colby, Hermann and Bryan.

The meeting adjourned to partake of a light lunch arranged by the Entertainment Committee.

F. E. Bausch, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, March 2, 1900.—Called to order at 8.30 p.m. by Vice-President Falkenau.

The minutes of the last regular meeting were read and approved.

Mr. J. H. G. Wolf was elected a member of the Society, and declared so upon a count of ballots.

Mr. C. E. Grunsky, City Engineer, addressed the members informally on the subject of the "Proposed Sewer System for San Francisco," which was discussed at length by those present.

Profs. Frank Soulé and H. I. Randall, as a committee, presented a memorial on the death of the late H. H. Hirst, member of the Society, which was ordered to be published in the Journal, in an appropriate form, together with a photograph of the deceased.

Adjourned.

Otto von Geldern, *Secretary.*

Detroit Engineering Society.

Regular Meeting, March 16, 1900.—The meeting was called to order at 8.20 p.m. by President Keep, in the parlors of the St. Claire Hotel. On account of the absence of the Secretary, Mr. Field was requested to act as Secretary *pro tem.* No business was transacted.

The speaker of the evening, Mr. B. O. Tippey, Superintendent of the Detroit City Gas Company, was introduced by the President, and gave an interesting talk on "Manufactured Gas," supplemented by drawings and tables in chart form. At the conclusion of the paper a general discussion followed, which was led by Messrs. Keep and Dow. The following names were proposed for membership: Mr. E. S. Wheeler, of the United States Engineer's Office, and Mr. H. L. Woolfenden, of Gilbert Wilkes & Co.

Attendance fifteen. The meeting adjourned at 9.15.

H. G. Field.

Civil Engineers' Society of St. Paul.

St. Paul, Minn., March 5, 1900.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 p.m. Present, seven members and ten visitors.

Minutes of previous meeting read and approved.

Mr. Arthur Lipschutz read a paper on "Acetylene for Railway Station and Train Lighting," and Mr. Max Toltz cited some facts as to train lighting in general. The thanks of the Society were tendered, and both were requested to prepare their work for publication in the Journal of the Association of Engineering Societies.

Mr. C. Webster Raynor was elected to membership.

C. L. Annan, *Secretary.*

Association of Engineering Societies.

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PROCEEDINGS.

Engineers' Society of Western New York.

Regular Meeting, February 6, 1900.—Meeting called to order at 8.00 p.m.; Mr. Haven, President, in the chair.

The following were present: Messrs. Haven, Diehl, Bardol, Tutton, Ricker, Bassett, Van Der Hoek, Cornell, Knighton, Roberts, March, Babcock, Tresise, Guthrie, Buttolph, Whitford, Speyer, Kielland, Chas. Fell, Geo. Fell, Rathman, Norton, Newell and others.

The minutes of the last regular meeting were read and approved.

Mr. Haven.—At the last meeting Mr. Tutton, of the Board of Managers of the Association of Engineering Societies, spoke about the rates for advertising in the Journal. I wrote to Mr. Trautwine in regard to the matter, and the Secretary will read his reply.

"Philadelphia, Pa., January 25, 1900.

"Mr. W. A. Haven, Buffalo, N. Y.

"*Dear Sir,*—Your letter of the 18th inst. was received here during my attendance at the annual meeting of the A. S. C. E., in New York last week, and was brought to my attention yesterday.

"By the order of the Board of Managers, any Society obtaining advertisements for the Journal is entitled to 90 per cent. of the gross amount paid to the Association for the advertisement, and our custom is, after the advertisement is paid to the Association, to send the Society an Association check for its ninety per cent.

"The Engineers' Club of Philadelphia has in past years covered the entire cost of publishing its proceedings by means of its advertisements, and, as I remember the report of last year, they collected from advertisements about $600, or approximately one-half of the cost of the Journal for that year. I can see no reason why our Societies should not do the same, thereby greatly reducing their net payments to the Association, and their assessments upon their members.

"Of course, as you remarked, high-salaried railway officials can hardly be expected to advertise extensively, but I have no doubt that some, at least, of your members are interested in large concerns which could well afford to take a page or so.

"Yours truly,

(Signed) "John C. Trautwine, Jr., *Secretary.*"

Mr. Haven.—You will see by this it does not mean simply the advertising of the individual members, but anybody you can get. I think some of you can save money for the Society by doing this.

The Executive Committee has authorized the President and Secretary to sign the lease of the room, No. 975 Ellicott Square, and has directed the Library Committee to get our property from this building to the new room, and by the next meeting the room will be open for all time for the members, and they can get keys and have easy access to it.

The rent begins on the 15th of February.

I name a Library Committee this evening, consisting of Mr. Knighton, Mr. Babcock and Mr. Morse.

The Topic Committee for this month is Mr. Bardol.

Mr. Haven.—The Executive Committee has considered the resolution passed by the Society at the annual meeting, and now recommends that Thomas William Symons, Major of the Corps of Engineers of the United States Army, be elected honorary member of this Society. A rising vote was taken and Major Symons was declared to be unanimously elected.

The Secretary was directed to notify Major Symons of his election as honorary member.

Mr. Newell entertained the Society with a very complete paper on "Central America," the people, climate, earthquakes, rainfall, Nicaraguan Çanal, volcanoes, etc., after which an interesting discussion took place, Mr. Newell kindly answering all questions asked by the members.

The meeting passed a vote of thanks to Mr. Newell.

Mr. Bardol reviewed the history of the South Buffalo floods, and the plans advocated to abate the same. In brief, Mr. Bardol said: "That while plan 'A' will do the work which is intended, and it has always been advocated by the department, it is a plain proposition that the plan that will give the best satisfaction in the end will be the one which will most shorten up the river, and the city should exhaust every effort to have this done before actually beginning work on any plan."

A vote of thanks was extended Mr. Bardol.

Mr. Norton explained about the Old South Channel from the records in the County Clerk's office.

Mr. Whitford mentioned that Sewell Bennett could probably inform the Society about the South Channel, as his father furnished part of the money for building it.

On motion of Mr. Ricker, meeting adjourned at 10.15 P.M.

G. C. Diehl, *Secretary.*

Regular Meeting, March 5, 1900.—Meeting called to order at 8.30 P.M.; Mr. Haven, President, in the chair.

The following members present: Messrs. Haven, Fields, Dr. G. E. Fell, Roberts, Morse, Sikes, Diehl, Bardol, Lufkin, Guthrie, Meyers, Tench, Carlton, Knighton, Buttolph, Whitford, Ricker, Kielland and sixteen visitors.

On motion, it was voted that the rules be suspended in regard to the order of business to listen to an address by Mr. Buchanan, the Director-General of the Pan-American Exposition.

Mr. Buchanan was introduced to the Society by Mr. Haven, after which the Society listened to an entertaining address by Mr. Buchanan on the railways, docks, etc., in Argentine Republic.

Among other things Mr. Buchanan said that the railways in South America were among the best equipped and best managed of any foreign roads. The roads have been built under a Government guarantee, a Board of Managers has supervision over all the workings of the roads and the roads are a paying investment. The Madeira docks are among the finest in the world and were built in the face of almost insurmountable difficulties.

A vote of thanks was tendered to Mr. Buchanan.

Dr. Geo. E. Fell.—I believe all of us would like to hear from Mr. Buchanan on the Pan-American Exposition.

Mr. Buchanan.—This Exposition will do more to make known and improve your city than anything else you could possibly dream of.

A gentleman, I think a member of your Common Council, remarked that the people of the city of Buffalo need to be discovered.

The interest in the Exposition is great throughout the country. We have applications for space from several South American countries who have declined to make an exhibit at Paris, and these countries will be represented at your Exposition.

The work is going on steadily. There is no loss of time, and the Exposition will be built on time and will be a success, provided the people of Buffalo take the proper interest in it.

No budget has been made, can be made or will be made. I made a budget in 1890—my last in 1893. I do not think I score very high as a budget-maker. I made a good average with the rest of them, that is all the satisfaction I got out of it.

(Applause.)

Mr. Haven.—Since the last regular meeting we have moved into our new rooms, No. 975 Ellicott Square. A key-book has been prepared by the Secretary, who will supply you with keys to the rooms.

You have elected, by ballots in the usual way, the following gentlemen since the last meeting: Messrs. Kielland, Tench, Lewis, Wilson and Rogers. (Mr. Kielland and Mr. Tench, being present, were introduced to the Society.)

I also wish to announce that applications have been received by the Society from Horatio A. Foster, whose application is indorsed by Messrs. Ricker, Morse, Guthrie and Diehl. Also from Geo. F. Lucas, of Castile, N. Y., the gentleman who makes steel tapes, and is also the county surveyor of that county, indorsed by Messrs. Haven, Bardol, Guthrie and Diehl. These applications will be presented to you during the coming month.

It was moved by Mr. Guthrie and seconded by Mr. Fields that the reading of the minutes of the last regular meeting be dispensed with.

Carried.

The following letter from Major Symons was read by the Secretary:

"Buffalo, N. Y., February 20, 1900.

"Mr. Geo. C. Diehl, Secretary Engineers' Society of Western New York.

"*Dear Sir*,—Your letter of February 16, announcing my election as an honorary member of the Society, has been received.

"Permit me to thank you and the Society, and to say that I appreciate the honor very much and that I shall hold the interests of the Society very near to my heart. "Very sincerely yours,

(Signed) "Thomas W. Symons."

Mr. Haven.—I also had a letter from Major Symons, in which he said the notification was a very happy birthday present.

Mr. Buttolph.—I move that when we adjourn, we adjourn to room No. 975 Ellicott Square.

Carried.

Mr. Knighton.—Referring to the communication of Mr. Trautwine, of January 25, 1900, to our President, in relation to advertisements, I offer the following resolution:

Whereas, By order of the Board of Managers of the Association of Engineering Societies any Society obtaining advertisements for the Journal is entitled to 90 per cent. of the gross amount paid to the Association for the advertisement;

Resolved, That any member of our Society securing an advertisement to be inserted in the Journal of the Associated Societies whereby the Society shall receive 90 per cent. of the gross amount paid to the Association, this Society agrees to pay to the member securing such advertisement — per cent., provided such member shall not be in arrears of dues to the Society.

Mr. Haven.—I think it is a very good thing to do. If the Society gets 90 per cent. for an advertisement, it can well afford to pay 30 or 40 per cent to the member securing the ad., and I would like to suggest that the blank be filled in with 40 per cent.

Mr. Diehl.—The resolution says, "except such member is not in arrears of dues to the Society." If the Society gets 90 per cent., it would be better to pay 40 per cent. to such members and possibly we could get the dues paid up.

Mr. Haven.—Amendment accepted.

Resolution, as amended, to read as follows:

Whereas, By order of the Board of Managers of the Association of Engineering Societies, any Society obtaining advertisements for the Journal is entitled to 90 per cent. of the gross amount paid to the Association for the advertisement;

Resolved, That any member of our Society securing an advertisement to be inserted in the Journal of the Associated Societies whereby the Society shall receive 90 per cent. of the gross amount paid to the Association, the Society agrees to pay to the member securing such advertisement 40 per cent. of the amount received from the Association.

Question put, motion lost.

Mr. Haven.—I am sorry that the motion has been lost. Will some of the gentlemen who have objected to it state their reasons?

Mr. Ricker.—It does not seem to me that the Society should take this position of paying a rebate to members. It looks too much like a tax collector. If a man cannot through love, patriotism, sentiment or regard for this Society interest himself for the good of the Society, he should not be given an inducement to do so. What is done should be done for the Society itself, and not with the idea that a rebate is to be paid.

Meeting adjourned to No. 975 Ellicott Square, at 10 p.m.

G. C. Diehl, *Secretary.*

Regular Meeting, April 2, 1900.—Meeting called to order at 8.20 p.m.; Mr. Haven, President, in the chair.

The following members present: Messrs. Haven, Tench, Sikes, Kielland, Van Der Hoek, Lufkin, Diehl, Speyer, Rogers, Bardol, Bassett, Buttolph, Knighton, Knapp, Cornell, C. F. Fell, Roberts and five visitors.

It was moved and seconded that the reading of the minutes of the last regular meeting be dispensed with, and that they be approved as printed.

Carried.

Mr. Haven.—You have elected as members of the Society Messrs. George F. Lucas and Horatio A. Foster, and the Secretary will please notify these gentlemen of their election.

Mr. Knighton, on behalf of the Library Committee, reported that two meetings had been held, and the matter of bookcases considered. The committee, after correspondence with makers of bookcases, had decided to sell to the Society of Natural Sciences, for $50, the old bookcase, now in the rooms at the library building.

Mr. Knighton urged the binding of periodicals, and the matter was referred to the Library Committee, with power.

Mr. Haven announced that he had corresponded with the chief engineers of several railroads, asking them to furnish, for the Society, copies of their most recent specifications for steel structures, especially for railroads. The following officers have complied with this request. A vote of thanks to these gentlemen was passed unanimously: C. W. Buchholz, chief engineer, Erie Railroad, New York city; E. H. McHenery, chief engineer, Northern Pacific Railroad, St. Paul; W. J. Wilgus, chief engineer, New York Central Railroad, New York City; Joseph Hobson, chief engineer, Grand Trunk Railroad, Montreal; William A. Pratt, engineer of bridges, Pennsylvania Railroad, Philadelphia; J. H. Graham, chief engineer, Baltimore and Ohio Railroad, Baltimore; J. E. Blunt, chief engineer, Chicago and Northwestern Railroad, Chicago; W. L. Breckenridge, chief engineer, Chicago, Burlington and Quincy Railroad, Chicago; J. B. Berry, chief engineer, Union Pacific Railroad, Omaha. The Canadian Pacific Railroad had replied that specifications, now being printed, would be forwarded as soon as completed.

Mr. Louis H. Knapp, Chief Engineer of the Water Department, was then introduced to the Society by the President, and spoke on the subject, "Water Supply for the Pan-American," as follows:

Mr. President and Members of the Society: The water supply or distribution of the city of Buffalo consists of about 500 miles of cast iron pipe, varying in size from 3 inches to 48 inches in diameter, about 5000 hydrants and 7000 valves.

The city is divided in its fire protection into a business district and a residence district. The business district is bounded on the north by North street, on the east by Michigan street and on the south and west by the water front. The hydrants in this business district are located about 300 feet apart; those in the residence district about 500 feet apart. The water supply in the business district is about 600 gallons per minute per hydrant, and in the residence district about 300 gallons per minute. The pipes are proportioned to carry a sufficient amount of water at a velocity of 2½ feet per second to supply the amount. In the business district we can supply thirty steamers at any point, and in the residence district ten steamers.

In the business district we have a 48-inch main in North street; Allen street, a 24-inch; through Virginia street, a 20-inch; through Tupper street, 20-inch; through Huron and Sycamore, 36-inch; through Court and Clinton streets, 36-inch; North Division street, 16-inch, and Exchange street, 20-inch. You will notice that the large pipes are located in the streets run-

ning east and west, and the smaller sized pipes in the streets running north and south. This is so on account of the location of the pumping station. Buffalo has a large amount of 6-inch pipes, also a large amount of larger pipes. In fact Buffalo probably is the only city in the world that can supply 400 gallons per capita and at the same time keep up the fire pressure on its mains.

In 1872, immediately after the Chicago fire, the city abandoned the idea that a fire stream could be obtained through a 4-inch pipe; and, in 1882, the city followed the practice of the city of Boston after its fire, to put in no pipes of less than 12 inches in the business district; following that custom, all pipes in the business district are made 10 inches in diameter. We are able to get the same results with a 10-inch pipe on account of the large pipes running east and west as Boston can with 12-inch pipes.

In the improvement of the city one of the requirements is that the water pipes shall be laid in advance of the pavement, consequently in such streets as Bailey and Kensington avenues large pipes are laid, diminishing toward the city line; so that in the outlying districts of the city the necessary mains are laid for some fifteen or twenty years to come.

If the Pan-American had been located at Riverside Park, we would have been unable to furnish them with a large amount of water, because as you approach the city line the pipe decreases in size. A separate pumping station would have had to be built to furnish them with sufficient water.

If the Pan-American had been located at the Front, we could have furnished them the water required without any great expense.

The present site is surrounded by a belt line of large pipes. At first they asked us for 3,000,000 gallons in twenty-four hours; in a few months they have asked us to increase this to 5,000,000. In order to supply them with 5,000,000 gallons per day and keep up the pressure at Central Park, Highland Park and the Poorhouse, we have decided to reinforce these pipes by a 20-inch main in Delaware avenue from Delavan avenue to Amherst street. It is only necessary at the pumping station to add another engine; that is taken off from the reservoir and put on the high service. The railroads will receive water for their engines from the pipe in Hertel avenue. The distribution of water inside of the grounds is for the company to arrange; we will furnish water for drinking fountains, sprinkling and everything of that kind. This problem is very simple. It is no more difficult to supply 5,000,000 gallons at this point (Pan-American site) than it was to furnish the same amount to the Grape Sugar Works, on Scott street, some years ago. Gentlemen, I think this is all I can say about the water for the Pan-American.

(Applause.)

In reply to questions, Mr. Knapp stated as follows: If much water is wanted by the Pan-American for lakes and fountains, it will have to establish a pumping plant at the Scajaquada Creek and draw its water from the harbor. It can then flow back into the creek. The city is not in position to supply any large amount of water where it goes to waste.

The elevation of the water in the Prospect reservoir is 116 plus city base. The highest point in the city is 125. We take the water at an elevation of 66 below the surface of the water in the reservoir, or elevation of 50 plus city base. We call that the dividing line between the reservoir and

high pressure. The surface of the city of Buffalo is very peculiarly situated. Black Rock is low; the highest point of the city is in the northeastern part. When the Kensington district is developed we will not be able to furnish them from the reservoir. A new supply to the district will be furnished.

Sixty per cent. of the water pumped is on the reservoir and 40 per cent. on the high service. The southern part of the city is not well built up; when it is, an additional plant will have to be built at Stony Point.

At the present time I think that the sewage of Buffalo contaminates the water of Tonawanda and Niagara Falls, though Mr. Buttolph may not agree with me. I think, however, that there is just as good water opposite Tonawanda and Niagara Falls as there is opposite Buffalo. If Tonawanda would go across Grand Island into the Canadian channel, and the same can be said of Niagara Falls, they would get good water.

Mr. Tench.—The Canadians make no complaint of bad water.

Mr Knapp.—They can get good water at both Tonawanda and Niagara Falls if they go out into the Canadian channel; they cannot get good water in the American channel. The great beauty of Buffalo water is that the water is thoroughly aerated.

The water furnished to the Pan-American is to be metered, so that the water department will get credit for what it pumps, although possibly the city will not get any money for it.

Seventy per cent. of the water pumped in Buffalo is wasted. We have to-day in Buffalo nine engines with a total pumping capacity of 200,000,000 gallons of water per day. If a meter was placed on every supply in Buffalo, one engine would be able to supply the whole city. The problem in Buffalo to-day is to restrict the waste. One engine on the high service working at 80 pounds per square inch would supply the city if this waste was stopped. We pumped 400 gallons per capita or 160,000,000 in twenty-four hours during zero weather.

Mr. Haven.—Has any account been kept as Mr. Trautwine has done in Philadelphia?

Mr. Knapp.—No, sir, not exactly; but it could be done very easily.

Mr. Haven.—I see by his report the great number of gallons wasted by just a drop, drop, drop from a faucet leaking.

Mr. Diehl.—I move that a vote of thanks be extended to Mr. Knapp for his very interesting address, Seconded by Mr. Buttolph.

Carried unanimously.

Meeting adjourned at 9.45 P.M. G. C. Diehl, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., February 21, 1900.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, Boston, at 7.50 o'clock P.M.; President C. Frank Allen in the chair. Seventy-eight members and visitors present.

The records of the last meeting and of the special meeting of February 1, were read and approved.

Messrs. Edmund M. French and John E. Titus were elected members of the Society.

The President reported for the Board of Government a recommendation that the eighteenth annual dinner of the Society be held on March 6,

and on motion it was voted that the annual dinner be held on that date, and that Mr. Henry Manley be a committee to make the necessary arrangements.

The thanks of the Society were voted to Mr. Ralph E. Curtis for the interesting paper read at the informal meeting of the Society held on January 17, 1900.

A letter was read from Mr. Andrew D. Fuller resigning the office of Librarian, on account of absence from Boston. On motion the resignation was accepted, and the Board of Government requested to take charge of the Library.

The Secretary read a memoir of Mr. Samuel Nott, an honorary member of the Society, prepared by Messrs. L. B. Bidwell and Edward Sawyer, a committee of the Society.

Mr. George B. Francis then gave a very interesting talk, illustrated by the stereopticon, on the construction of the South Terminal Station in Boston.

Adjourned. S. E. Tinkham, *Secretary.*

Boston, Mass., March 21, 1900.—The annual meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, Boston, at 7.50 o'clock p.m.; President C. Frank Allen in the chair. Sixty-three members and visitors present.

The record of the last meeting was read and approved.

Messrs. Clarence T. Fernald, William B. Hunter, Harry L. Kimball, Leonard P. Kinnicutt and Frank E. Waterman were elected members of the Society.

The Secretary read a memoir of Charles E. C. Breck, a member of the Society, prepared by Messrs. Joseph H. Curtis and Channing Howard, a committee of the Society.

The annual report of the Board of Government was read by the President, and by vote it was accepted.

The reports of the Secretary and Treasurer were read respectively by those officers, and by votes they were accepted.

The report of the Committee on Excursions was read by Mr. Metcalf, and by vote it was accepted.

The report of the Committee on the Library was read by the Secretary, and by vote it was accepted.

Mr. FitzGerald, for the Committee on Quarters, made a brief verbal report, which was accepted.

On motion of Mr. FitzGerald, the sum of $50 was appropriated for the purchase of standard engineering books.

On motion of Mr. Brackett, it was voted to refer to the Board of Government, with full powers, the question of continuing the several special committees of the Society and the selection of the membership thereof, and also the question of printing the various reports which have been received this evening.

On motion of Mr. Flinn, the sum of $50 was appropriated for the use of the Librarian for clerical assistance.

On motion of Prof. Swain, the Board of Government was authorized to transfer, during the year, the sum of $2000 from the current fund to the permanent fund of the Society.

Messrs. A. G. Robbins and I. T. Farnham, the tellers of the election, submitted the result of the letter ballot, and, in accordance with their report, the President announced the election of the following officers:

President—Alexis H. French.

Vice-President (for 2 years)—Frank W. Hodgdon.

Secretary—S. Everett Tinkham.

Treasurer—Edward W. Howe.

Librarian—Louis F. Cutter.

Director (for 2 years)—Ira N. Hollis.

President C. Frank Allen then delivered the annual address of the retiring President, entitled "The Outlook for Engineers."

Before declaring the meeting adjourned, President Allen, in a very felicitous manner, introduced his successor, Mr. French, who thanked the members for the honor they had conferred upon him in electing him President of the Society for the ensuing year.

Adjourned.

S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1899-1900.

Boston, March 21, 1900.

To the Members of the Boston Society of Civil Engineers:

In compliance with the provisions of the Constitution, the Board of Government submits its report for the year ending March 21, 1900.

At the last annual meeting the total membership of the Society was 484, of which 473 were members, 5 honorary members and 5 associates. During the past year we have lost 22 members; 5 by death, 9 by resignation and 8 by forfeiture of membership for non-payment of dues. There have been added to the Society during the year 28 members; 23 of these have been new members elected, 1 was transferred from the Montana Society of Engineers and 4 former members of the Society have been reinstated. Our present membership consists of 2 honorary members, 6 associates and 482 members; a total of 490.

The record of deaths during the year is: Charles Herbert Swan died April 17, 1899; Sumner Hollingsworth died June 26, 1899; John H. Blake died July 5, 1899; Samuel Nott died October 1, 1899; William Scollay Whitwell died October 31, 1899.

Of these, three were honorary members. John H. Blake was the first Secretary of the Society, and Samuel Nott the second, his term of office extending over many years. These two, with William S. Whitwell, had been members of the Society from the beginning. By their deaths, all occurring in the 52d year of the Society's existence, there is severed the last tie binding us to the earliest history, the organization of this Society. We are, however, fortunate in retaining something more than a pleasant memory of the early days, in the existence, as an honorary member, of Charles H. Haswell, who was elected a corresponding member of the Society in 1850, and who, at an advanced age, is still engaged in the active practice of his profession, who finds opportunity even now to exercise his privilege of voting for officers, and whose further interest in the Society is shown by the following extract from a letter to Mr. Henry Manley on the occasion of the last annual dinner:

"I regret the impracticability of my meeting the members of the Boston Society of Engineers on the 5th inst., as I would have anticipated

much pleasure in meeting its members on a social occasion. As a Boston bred boy, 1809 to 1819, I am pleased to know of the success of the Society of which I have the honor of being a member."

Ten regular and three special meetings of the Society have been held during the year, and the eighteenth annual dinner was given at the Hotel Vendome on March 6, 1900. The average attendance at the regular and special meetings was 79, the largest being 160 and the smallest 51. The attendance at the annual dinner was 141.

The following papers have been read at the several meetings:

March 15, 1899.—"Sewage Pumping Station and the Precipitation Tanks at Providence, R. I.," by Otis F. Clapp. (Illustrated.)

April 17, 1899.—"Construction of the New Bedford and Fairhaven Bridge," by William F. Williams. (Illustrated.)

May 2, 1899.—"A Trip to Porto Rico," by Leonard Metcalf. (Illustrated.)

May 17, 1899.—"Covered Reservoirs and their Design," by Freeman C. Coffin.

Discussion by Frank L. Fuller.

June 21, 1899.—"Description of the Plant of the New England Gas and Coke Co.," by Louis J. Hirt. (Illustrated.)

September 20, 1899.—"Account of a Recent Visit to Egypt and Europe," by Howard A. Carson. (Illustrated.) Memoirs of Thomas Doane and of Charles H. Swan.

October 18, 1899.—"Mechanical Draft for Steam Boilers," by Walter B. Snow. (Illustrated.)

November 15, 1899.—"Protective Coatings for Structural Metals," by Prof. A. H. Sabin.

December 20, 1899.—"Sand Filter Beds and Steel Conduit of the Albany, N. Y., Water Works," by William B. Fuller. (Illustrated.)

January 12, 1900.—"Construction of the Longwood Avenue Bridge," by Alexis H. French. (Illustrated.)

January 24, 1900.—"Recent Experiment on the Bacterial Treatment of Sewage in England," by Prof. Leonard P. Kinnicutt. Memoirs of William S. Whitwell and of Sumner Hollingsworth.

February 1, 1900.—"Description of the Metropolitan Water System," by Frederic P. Stearns. (Illustrated.)

February 21, 1900.—"Construction of the South Terminal Station in Boston " by George B. Francis. (Illustrated.)

Ten informal meetings have been held in the Society's library during the past year, with a much larger average attendance than in any previous year.

The subjects discussed at these meetings have been as follows:

March 22, 1899.—"Work Now in Progress for the Improvement of the South Bay, Boston," by Henry S. Adams.

March 29, 1899.—"Some Problems and Details of Landscape Engineering," by Edward P. Adams.

December 6, 1899.—"Work of the Metropolitan Water Board on Spot Pond," by W. E. Foss and J. L. Howard.

December 13, 1899.—"Cadastral Surveys," by Henry B. Wood.

December 27, 1899.—"Park Construction in Cambridge," by J. Albert Holmes.

January 10, 1900.—"Boston Elevated Railway Construction," by George A. Kimball.

January 17, 1900.—"Some Station Construction Work of the Edison Electric Illuminating Company in 1899," by Ralph E. Curtis.

February 14, 1900.—"Construction of Boat Harbors along the South Shore of Massachusetts," by John R. Burke.

February 28, 1900.—"Charlottetown Sewerage Works," by Freeman C. Coffin.

March 14, 1900.—"Details of the Steel Construction of the Boston Elevated Railway," by Joseph R. Worcester.

In accordance with the recommendation of this board, the Society appropriated last year $50 for the purchase of standard engineering works. Books to the cost of nearly the full amount have been purchased and added to the library. The board recommends that the sum of $50 be appropriated for the purchase of standard engineering works during the coming year. The board also recommends that it be authorized to expend a sum not more than $50 for clerical assistance for the Librarian during the coming year.

The report of the Treasurer indicates continued financial prosperity during the year. The permanent fund is now a trifle in excess of $10,000, and the current fund shows a surplus of $1910.43. The board recommends that during the coming year the sum of $2000 be transferred from the current fund to the permanent fund of the Society.

During the year, under the authority given by vote of the Society, there has been executed with the Tremont Temple Baptist Church a lease for three years, with the privilege of renewal for three years upon the same terms. A lease has also been executed with the New England Water Works Association for three years. The lease with the Hersey Manufacturing Company has not been renewed. It seemed wise both from the point of view of the tenant and of the Board of Government that the occupation should not be under a lease. The Hersey Manufacturing Company still occupies the room as tenant at will.

The record of the year would not be complete without mentioning the gift to the Society of an excellent portrait, in crayon, of Thomas Doane, who was for so many years President of this Society, and up to the time of his death an earnest and interested member. The portrait was the gift of Charles A. Pearson, a member of the Society, and for many years an assistant to Mr. Doane.

An event of exceptional interest and pleasure was the annual excursion of the Canadian Society of Civil Engineers, which was held in Boston, in February, about 60 members constituting the party. A program of excursions suitable for winter was arranged by a committee of this Society, covering the three days of their visit here. A special meeting of the Society was also held at which Mr. Frederic P. Stearns gave a description of the Metropolitan Water System, the works of which, though now under construction, it was not feasible to visit on account of the weather. After the meeting a lunch was served in rooms adjoining the hall and the Society rooms. During one of the evenings of their stay, the Canadian Society held their "Members' Annual Dinner," to which they very generously invited many of the members of our Society who had had opportunity to show them special courtesies. The appreciation shown by the Canadians as guests, and their whole-souled hospitality as hosts for an evening, made their visit here most enjoyable to all who were able to meet them in either the capacity of guest or host.

Our own annual dinner also gave opportunity as usual for a pleasant interchange of courtesies with many of our sister Societies of Engineering.

Respectfully submitted for the Board of Government.

C. Frank Allen, *President.*

Abstract of the Treasurer's and Secretary's Reports for the Year 1899-1900.

CURRENT FUND.

Receipts:		
Dues from new members	$110.00	
Dues for year 1896-1897	5.00	
Dues for year 1898-1899	16.00	
Dues for year 1899-1900	3,332.50	
Dues for year 1900-1901	54.00	
Rent of rooms	1,050.00	
Sales of Journals	6.25	
Fines on books and sales of periodicals	4.09	
Interest on deposits	31.33	
Balance on hand March 15, 1899	926.99	
		$5,536.16
Expenditures:		
Rent	$1,710.00	
Association of Engineering Societies	625.50	
Secretary's salary	400.00	
Printing, postage and stationery	383.00	
Periodicals and binding	111.55	
Incidentals	93.84	
Annual dinner	48.25	
Books and pamphlets	61.50	
Stereopticon at meetings	100.00	
Furniture and repairs	67.74	
Expenses of Excursion Committee	17.51	
Lighting room	6.84	
		$3,625.73
Balance on hand		$1,910.43

PERMANENT FUND.

Receipts:		
Twenty-three entrance fees	$230.00	
Shares of Merchants' Co-operative Bank, retired	1,812.98	
Subscription to Building Fund	100.00	
Interest and dividends	140.54	
Balance on hand March 15, 1899	900.01	
		$3,183.53
Expenditures:		
Dues on shares Merchants' Co-operative Bank	$332.00	
Dues on shares Workingmen's Co-operative Bank	300.00	
Dues on shares Volunteer Co-operative Bank	300.00	
Deposit in Warren Institution for Savings	1,008.75	
Deposit in Institution for Savings in Roxbury	1,000.00	
Deposit in Provident Institution for Savings	38.87	
Deposit in Boston Five-cents Savings Bank	38.37	
		3,017.99
Balance on hand		$165.54

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 21, 1900.

One Republican Valley R. R. bond (par value)	$600.00
25 shares Merchants' Co-operative Bank	1,707.25
25 shares Workingmen's Co-operative Bank	1,656.50
25 shares Volunteer Co-operative Bank	1,605.75
Deposited in Provident Institution for Savings	1,140.34
Deposited in Boston Five-cents Savings Bank	1,126.25
Deposited in Institution for Savings in Roxbury	1,000.00
Deposited in Warren Institution for Savings	1,008.75
Deposited in Old Colony Trust Company	165.54
	$10,010.38
Amount belonging to Permanent Fund March 15, 1899	9,252.91
Increase during year	$757.47

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund	$10,010.38
Current Fund	1,910.43
	$11,920.81
Total Amount March 15, 1899	10,179.90
Total increase during the year	$1,740.91

REPORT OF COMMITTEE ON EXCURSIONS.

BOSTON, March 21, 1900.

To the Members of the Boston Society of Civil Engineers:

Your Excursion Committee hereby presents its annual report.

Ten excursions, exclusive of those arranged for the recent visit of the Canadian Society of Civil Engineers to Boston, were made during the year, as follows:

April 20, 1899.—To the low service pumping station of the Metropolitan Water Board at the Chestnut Hill Reservoir, Brighton, Mass. Attendance, 27.

May 17, 1899.—To the Charles River Speedway of the Metropolitan Park Commission, Brighton, Mass. Attendance, 22.

June 21, 1899.—To the New England Gas & Coke Company's works at Everett, Mass. Attendance, 60.

July 19, 1899.—To the Scherzer Patent Rolling Lift Bridge carrying the tracks of the New York, New Haven and Hartford Railroad over Fort Point Channel; the city's Summer Street Bridge over Fort Point Channel; and the chocolate factory of the Walter M. Lowney Co., all located in Boston. Attendance, 90.

August 23, 1899.—A harbor trip to the Harbor and Land Commissioner's new State dock at South Boston; the city sewage pumping station and the New England Sanitary Product Company's garbage disposal plant at Cow Pasture; the new city sewage storage basins at Moon Island, and the pumping station of the Metropolitan Sewerage Commission at Deer Island. Attendance, 60.

October 21, 1899.—To the new pumping station, gate house, dikes, stripping and grading work of the Metropolitan Water Board at Spot Pond, and at the high service reservoir in Middlesex Fells. Attendance, 45.

November 15, 1899.—To the pumping station and chemical precipitation sewerage plant of the city of Providence at Fields Point, and the Providence Gas Company's gas pipe river crossing under the Seekonk River. Attendance, 36.

December 20, 1899.—To the city of Boston's Summer Street Bridge over Fort Point Channel, and the Summer Street Extension bulkheads; the abolition of grade crossings through the freight terminals of the New York, New Haven and Hartford Railroad at Summer street; Lawley's shipbuilding yard, in South Boston; and the Boston Electric Light Company's plant at the L Street Power Station, South Boston. Attendance, 40.

January 10, 1900.—In the evening, to the viaduct of the Boston Elevated Railway Company, under construction along Washington street, Roxbury. Attendance, 126.

March 21, 1900.—To the Engineering Laboratories and Civil Engineering Department of the Massachusetts Institute of Technology. Attendance, 44.

The total attendance upon these excursions amounted, therefore, to 550, or 50 less than the 600 of last year. These figures indicate, however, an encouraging and growing general interest in the excursions to view construction work, if it be borne in mind that of the 600 members participating last year, 230 were numbered on one excursion, that to Fort Independence to witness the explosion of two defective mines in the harbor.

Your committee's report would not be complete without reference at least to the excursions planned in conjunction with the Board of Government for the members of the Canadian Society of Civil Engineers on the occasion of their recent convention in Boston, in which excursions some of our members participated as hosts and guides.

Sixty of the members of the Canadian Society of Civil Engineers came to Boston. The excursion parties usually numbered from fifty to seventy-five, though in some cases small parties of five, ten or fifteen made trips other than the regular excursions planned for the Society. The following list constitutes the general excursions made:

February 1, 1900.—To the Massachusetts Institute of Technology; the Back Bay Station of the New York, New Haven and Hartford Railroad and the South Terminal Station, plant, yard, bridges, etc.; the Summer Street Extension Bridge over Fort Point Channel, and through the entire subway.

February 2, 1900.—To the New England Gas and Coke Company's works, at Everett; the construction work of the Boston Elevated Railway Company at Washington and Dudley streets; through Brookline to the Chestnut Hill Reservoir and Pumping Station, and the Brookline Natatorium.

February 3, 1900.—To the Boston Public Library; the Lawrence Experiment Station of the Massachusetts State Board of Health; the Brockton Filter Beds and Pumping Station, and Harvard University.

The Excursion Committee's Treasurer reports a cash balance of $20.66 in the hands of your committee.

Respectfully submitted,

Henry F. Bryant, *Chairman,*
Leonard Metcalf, *Secy. and Treas.,*
Charles W. Sherman,
Arthur B. Corthell,
Daniel L. Turner.

Committee on Excursions.

REPORT OF COMMITTEE ON THE LIBRARY.

BOSTON, March 21, 1900.

To the Boston Society of Civil Engineers:

In presenting this brief report, the Committee on the Library regrets the absence of Mr. A. D. Fuller, who was Librarian from May, 1899, to January, 1900. While Librarian, Mr. Fuller devoted a large amount of time to the library and carried on the good work of his predecessors. It was hoped that he might find time to prepare this report before leaving for Paris to take up his work in connection with the Exposition. In his absence we submit the following brief statement in relation to the library:

Since the last annual meeting of the Society there have been added to the library 621 titles. Of this number, 363 are pamphlets and paper-covered reports, and 258 are bound volumes; 21 volumes of standard engineering books have been purchased from the appropriation made by the Society, 69 volumes of periodicals and reports have been bound and the remainder are gifts and exchanges. The Society has received a larger number of gifts for the library this year than in any previous year. From the estate of Thomas Doane, several hundred reports and pamphlets have been received which have not been catalogued as yet. During the year a new bookcase has been built, adding about 50 feet of shelf room to the library, and the periodical rack has been raised, furnishing greater space for the accommodation of the readers.

One hundred and thirty books have been borrowed from the library by members for home use and fines have been incurred for keeping books overtime, to the amount of 89 cents, which has been turned over to the Treasurer.

From the sale of a very few of the duplicate copies of periodicals belonging to the Society the sum of $3.20 has been received, which has also been paid to the Treasurer.

Your committee feels that as the work of the Librarian has increased materially during the past few years, an appropriation should be made by the Society to enable him to employ sufficient clerical assistance to do the work necessary to keeping the library catalogued up to date.

Respectfully submitted,

F. P. MCKIBBEN,
FREDERIC H. FAY,
CALEB MILLS SAVILLE,
Committee on the Library.

Louisiana Engineering Society.

NEW ORLEANS, SATURDAY, JANUARY 13, 1900.—The annual meeting of the Louisiana Engineering Society was called to order by President Raymond at 8.20 P.M., with eighteen members and two guests present.

The minutes of the last meeting were read and approved. The minutes of the Board of Direction were then read and ordered filed. Then followed the reports of the Secretary, Treasurer, Librarian, Chairman of the House Committee and Chairman of the Library Committee, all of which were received and ordered filed.

Under the head of Technical Exercises, President Raymond read his annual address, which was a masterly treatment of the part that the engineer has taken in the development of the State of Louisiana. Mr. Ray-

mond was given a rising vote of thanks by the Society for having contributed such a carefully prepared and valuable paper.

Mr. Malochee offered the following amendments to the Constitution, Article II, Section I, add the following: "Associate members shall have the right to vote"; Article VII, strike out in the first sentence the following: "which shall be confined to members," and add the new clause: "The right of voting shall be exercised by all members and associate members, and that of holding office shall be confined to members only." Received and ordered acted upon at future meetings.

The ballots upon the application of Mr. Alfred Raymond were then opened and canvassed, and resulted in his unanimous election to resident membership, thirteen votes being cast.

The balloting for the officers for 1900 was then declared in order, and the result was as follows:

President—Henry J. Malochee.

Vice-President—Alfred F. Theard.

Secretary—Gervais Lombard.

Treasurer—Walter H. Hoffman.

Director—T. H. Tutwiler.

Representative on Board of Managers of Engineering Societies—Thos. L. Raymond.

Notice was ordered given for the election of a Director, vice Henry J. Malochee, whose election to the Presidency necessitated his resignation as Director. His term still had two years to run.

After a few remarks by the new President, Mr. Malochee, during which he outlined a policy for the new administration, Mr. Lombard was requested to take the Secretary's chair. The new Treasurer, Mr. Hoffman, was not present.

The meeting adjourned at 10 P.M., and refreshments were served in honor of the occasion.

GERVAIS LOMBARD, *Secretary.*

THE new Board of Direction met at 2 P.M., Saturday, January 20, with President Malochee in the chair, and the following members present: Messrs. Theard, Hoffman, Lombard, Kerr and Tutwiler. Messrs. T. L. Raymond and J. F. Coleman were present by invitation.

A motion was put and carried directing the Secretary to notify delinquent members that according to Article IX of the By-laws they were suspended for non-payment of dues; but by forwarding to the Secretary the amounts of their indebtedness before the next meeting of the Board of Direction, say fifteen days, the said board will take pleasure in reinstating them in accordance with the discretionary power placed with them by said Article IX.

A motion was passed fixing the Saturday preceding the regular meeting of the Society as the regular monthly meeting day of the Board of Direction, at 1 P.M.

President Malochee appointed Mr. F. M. Kerr Chairman, and Messrs. T. H. Tutwiler and the unelected Director, members of the Auditing Committee. President Malochee then appointed Mr. J. W. Armstrong Chairman of the Library Committee, and Mr. Alfred F. Theard Chairman of the House Committee, the balance of the last two committees to be appointed at the next meeting.

A motion was passed whereby the following members were to be requested to read papers before the Society:

Maj. B. M. Harrod on "Shell Formation."

Mr. Haugh on "Pile Driving and Creosoting."

Mr. W. B. Wright on "Drainage of the Valley and of the City of Mexico."

Prof. J. M. Ordway on "Water Supply of New Orleans."

Alfred Raymond on "Electrical Features of the New Orleans Drainage System."

Benjamin Andrews, Jr., on "Irrigation Pumps and Artesian Wells."

Maj. H. B. Richardson upon some subject to be chosen later by himself.

Three applicants were approved by the Board of Direction and a preliminary list ordered sent out. The Secretary was ordered to have special envelopes prepared for the use of members in balloting.

The bill of H. C. Ramos for refreshments at the annual meeting, amounting to $7.50, was ordered paid.

The recommendation of the previous Board of Direction in regard to binding the back numbers of the magazines on hand, and in regard to buying another bookcase, were approved and ordered carried out.

A communication from the Engineering Association of the South, inviting our Society to join their Association as a chapter, was read and referred to President Malochee for investigation and a report.

A motion was carried reinstating Mr. Paul Andry, who had resigned. The meeting adjourned at 4.30 P.M.

GERVAIS LOMBARD, *Secretary.*

The Board of Direction held its regular monthly meeting at 1 P.M., February 10, 1900, with President Malochee in the chair, and the following members present: Messrs. Theard, Hoffman, Tutwiler and Lombard. Absent, Mr. Kerr.

After reading and approving the minutes of the previous meeting, a motion was carried approving the action of Chairman Theard, of the House Committee, in purchasing new curtains, poles, shades, etc., for the windows and approving the bills for the same.

A motion was put and carried whereby the Citizens' Bank was selected as the official depository of the Society.

A motion was then carried directing the Secretary to order a letter ballot upon the applicants whose names were sent out on the preliminary list of February 1.

By a resolution Messrs. A. L. Black and W. C. Kirkland were reinstated as resident members; and Mr. Geo. Blanchin was reinstated as associate member. Eight applications were read and the Secretary ordered to send out a preliminary list of the same. A communication was then read from Prof. Jno. M. Ordway, in which he accepted the invitation to read a paper upon "The Water Supply of the City of New Orleans." A motion was passed directing the Secretary to arrange for the use of a toilet stand for the rooms. The meeting adjourned.

GERVAIS LOMBARD, *Secretary.*

REGULAR MONTHLY MEETING, FEBRUARY 12, 1900.—The regular monthly meeting of the Society was called to order by President Malochee at 8 o'clock, with seventeen members and one guest present.

The minutes of the previous meeting of the Society were read and approved. The minutes of the last two meetings of the Board of Direction were read and ordered filed.

A communication from Mr. Arsene Perrilliat, in which he regretted that his absence from the city would prevent him from leading off in the "Informal Discussion," was read and ordered received.

Under the head of Reports of Officers, the reports of the Secretary and of the Treasurer were read. The Chairman of the House Committee made a verbal report, saying that what he had to report was plainly to be seen by glancing around the rooms. He had called upon the landlord to make numerous repairs which were necessary, and, as could be seen, the entire woodwork on the interior of the rooms had been freshly painted and the plastering repaired, without cost to the Society; but the new curtains, shades, poles, etc., had been purchased by the Society. Altogether, the rooms had been transformed into a cosy, clean, bright, comfortable and attractive place. The various reports were approved, with the exception of that of the Treasurer, which was referred to the Auditing Committee for correction.

The election of a Director, vice H. J. Malochee, was then proceeded with, and Mr. E. D. Ivy being the only nominee, the Secretary was instructed to cast the vote, thus unanimously electing Mr. Ivy as Director; his term to be two years. The amendment to the Constitution changing it so as to permit associate members to vote, and which was mentioned in the notices of the meeting, was then called up for consideration and ballot. After due consideration, a vote was taken and the amendment lost.

As neither Mr. Perrilliat nor Mr. Hardee, who were to have opened the informal discussion on "Building Levees by Machinery," was present, Mr. S. F. Lewis, one of the State Engineers, was requested to lead off. He did so in a very lucid and able manner and was followed by others. The informal discussion was altogether a success, a noticeable feature being the participation of associate members.

The Chair then announced that the technical exercises for the next meeting would consist of a paper by Mr. W. B. Wright, Assistant Engineer of the New Orleans Drainage Commission, on "The Drainage of the Valley and of the City of Mexico." He further announced that Prof. Ord way would read a paper at the April meeting on "Water Supply of New Orleans."

A motion was passed authorizing the President to appoint a Committee on Legislation. The meeting adjourned at 10.20 P.M.

GERVAIS LOMBARD, *Secretary.*

THE Board of Direction was called to order at 1 P.M., March 3, 1900, by Vice-President Theard, with the following members present: Messrs. Hoffman, Kerr and E. D. Ivy. Absent, Messrs. Tutwiler and Malochee.

The meeting was specially called for the purpose of opening the ballots upon the following applicants: For resident membership—Ernest Lee Jahncke, Richard T. Bond, S. Denis J. Villere, W. M. White, Will J. Gibbens. For associate membership—E. A. Grasser, Jos. E. Manning, Sidney A. Calongne. All of the above were elected unanimously. Twenty-five ballots were cast, showing the success of inclosing the members special balloting envelopes.

A motion was passed reinstating Mr. Jno. A. Fox for the purpose of permitting him to pay up his dues and resign for 1900. His resignation was then accepted. By a motion, the Secretary was authorized to pay out of petty cash all approved bills not amounting to more than two dollars.

A motion was passed instructing the Secretary to issue the new list of applicants for ballot on March 7. Meeting adjourned at 1.30 P.M.

GERVAIS LOMBARD, *Secretary.*

THE Board of Direction held its regular monthly meeting, March 10, 1900, which was called to order at 1 P.M. by President Malochee, with the following members present: Messrs. Hoffman, Kerr, Ivy, Lombard and Tutwiler Absent, Mr. Theard.

The minutes of the previous meeting were read and approved. The monthly reports of the Secretary and of the Treasurer were read and approved. Chairman Armstrong, of the Library Committee, submitted a report which was read and discussed. The Committee's recommendation that forty-one volumes, a list of which was enumerated, be bound, was approved. Their recommendation that the Society subscribe to the *American Electrician* was also approved. The recommendation that the subscription to the *Army and Navy* be discontinued was not acted upon because the subscription was already prepaid till December, 1900. Their recommendation for cases to file back numbers of our periodicals when bound was approved, and the Chairman of the House and the Chairman of the Library Committees were instructed to meet and call for estimates or bids, which should be submitted to the Board of Direction. The recommendation that a circular letter be sent to the various manufacturers inviting them to send the Society and its members catalogues, etc., was approved. Their recommendation that the attention of the Society, when in regular session, be drawn to specially interesting and pertinent articles in our journals and periodicals was approved, and the Board of Direction resolved that the Chairman and the members of the Library Committee be requested to look over said periodicals with that purpose in view, and to announce their findings to the Society at the regular meetings under the head of Technical Exercises.

Under the head of Communications the Secretary read favorable replies from the newly elected members and associate members, and regrets from Mr. Paul Andry, who had been reinstated. The communication from the Engineering Association of the South, relative to an exchange of journals, was read and the matter was referred to Mr. T. L. Raymond, the Representative on the Board of Managers of the Association of Engineering Societies, with instructions that he request Mr. Trautwine to place the Association of the South on their exchange list and also to send this Society a subscription.

The communication from the managers of the Louisiana State Fair was referred to the Society for consideration.

A bill from Palfrey Dameron & Co. for printing, amounting to $4.25, was approved. The Secretary was instructed to purchase a scrapbook, in which all press accounts of meetings, notices, etc., must be pasted. In this way the annual report of the Secretary could be more easily and interestingly prepared.

In order to simplify the method of paying bills, it was resolved that bills be paid but once a month. That is, that all bills should be held till the regular meeting of the Board of Direction for approval.

The Secretary was instructed by resolution to have a new list of members with their official titles, addresses, etc., printed.

The matter of an outing to Avery's Island Salt Mines was suggested.

The meeting adjourned at 2.30 P.M.

GERVAIS LOMBARD, *Secretary.*

REGULAR MONTHLY MEETING, MARCH 12, 1900.—The regular monthly meeting of the Society was called to order at 8.15 P.M. by President Malochee, with seventeen members and two guests present.

The minutes of the last meeting were read and approved. The minutes of the Board of Direction meetings were read for the information of the Society.

President Malochee announced the appointment of Mr. A. C. Duval and Mr. R. E. DeBuys as members of the House Committee, thus completing said committee, Mr. A. F. Theard having already been appointed Chair man.

The communication from the managers of the Louisiana State Fair was then read and considered, but as the time was too short in which to secure a new and creditable exhibit, it was decided not to make any exhibit this season.

Under the head of Technical Exercises, Mr. W. B. Wright read a very interesting and instructive paper upon the "Drainage of the Valley and of the City of Mexico." By unanimous vote, Mr. Wright received the thanks of the Society.

President Malochee then announced the following appointments upon the Legislative Committee: Messrs. J. F. Coleman, Chairman; W. J. Hardee, A. C. Bell, Arsene Perrilliat and Alfred Raymond.

The meeting adjourned at 9.45 P.M.

GERVAIS LOMBARD, *Secretary.*

APRIL 7, 1900.—The regular monthly meeting of the Board of Direction was called to order at 1 P.M. by Vice-President Theard, with the following members present: Messrs. Tutwiler, Kerr, Theard, Hoffman and Lombard. Absent, Messrs. Malochee and Ivy.

The minutes of the two previous meetings of the Board of Direction were read and approved. The Secretary and the Treasurer both submitted reports or statements which were received and approved. Secretary Lombard made a verbal report stating that he purchased a scrap book, as directed, but had not had the new list of members printed, because some of the recently elected members had not yet responded, but would do so now without delay.

Chairman Theard, of the House Committee, reported verbally that the Library Committee and the House Committee had agreed to purchase the Wernicke system of bookcases in the future, and had ordered such as were needed immediately at a cost of $19.

Under the head of communications, the Secretary read a number of letters as follows: A letter from the Civil Engineers' Club of Cincinnati, requesting our presence at their 20th anniversary and reception, which was held on March 29th. Ordered received. Letters from Jno. F. Richardson,

L. W. Brown and Judge Jno. Clegg, accepting election to membership, and one from Mr. Eugene Clapp regretting that he could not accept election. A postal from the Kenion News Company, stating that they would shortly ship us the back numbers of the periodicals we wrote for, together with a bill for same. This communication was referred to the Library Committee. A communication from Mr. Chas. H. Davis, a civil engineer in New York, asking for information in regard to his eligibility to membership of our Society, the dues, initiation fees, etc. The Secretary was instructed to send him the requested information. A communication from Mr. Geo. W. Rafter, member of American Society of Civil Engineers, stating that he sent by express a package containing such of his articles, papers, etc., as had been printed, and asking us to accept them as records for our library if we felt so disposed. The Secretary reported that the package had arrived, and the letter was referred to the Library Committee with full power to act. A communication from the Department of the Interior, U. S. Geological Survey, stating that the copies of the report upon the resources, etc., of the Island of Porto Rico were ready for distribution, and requesting us to write for one if we desired it. The Secretary was instructed to write on for one. A communication from Mr. F. T. Llewellyn, who is now in the City of Mexico, inclosing a long newspaper clipping from the *Mexican Herald* concerning the drainage of the Valley and of the City of Mexico, which has just been inaugurated. He thought it might serve as a basis of discussion at our next meeting, if Mr. Wright thought it added any new features to his paper. Received and filed. A communication from Mr. James G. Clark asking for permission to hang on the walls of our rooms a photograph of the new steel frame addition being erected by the American Sugar Refinery Company. Referred to the Secretary with full power to act, it being understood that we could not accept the photograph if it was in the shape of an advertisement. A communication from the Association of Engineering Societies asking for information in regard to the effect of our membership to their Association upon our exchange list. The action of the Secretary, who had answered the communication saying that so far, we had never had an exchange list to be affected, was approved. A communication from Mr. Blanchin, asking for a transfer from associate membership to resident membership. The Secretary was instructed to place his name on the next preliminary list sent out.

A bill for printing by Palfrey, Dameron & Company, amounting to \$1.75, was approved, as was one from Jas. E. Gelston, for collecting, amounting, at 10 per cent., to \$5.85.

GERVAIS LOMBARD, *Secretary.*

APRIL 9, 1900.—The regular monthly meeting of the Louisiana Engineering Society was called to order by President Malochee at 8.15 P.M., with twenty-five members and seven guests present.

The minutes of the last meeting of the Society were read and approved. The minutes of the last two meetings of the Board of Direction were read for the information of the Society.

The monthly statements of the Secretary and of the Treasurer were read and approved. President Malochee then called the attention of the Society to its flourishing and satisfactory condition, both as to membership, interest, and financial condition.

The Chairman of the Legislative Committee, who was appointed at the last meeting, reported progress, and urged early action in order to be

prepared for the coming session of the State Legislature. Hereupon Mr. Theard moved that the committee be authorized to insert in the official journal of the State a notice of intention to apply for the passage of a law regulating the professional practice in this State of the various engineering branches. Mr. Coleman offered as a substitute a resolution that the President of the Society be instructed to call a meeting of the Society in the near future to take up the question of legislation for the protection of the public and the profession. The substitute motion was put and carried, whereupon President Malochee named next Monday at 8 P.M. as the time for the meeting.

Two written notices were then offered by Mr. Theard, to be sent out with the notices of the next regular meeting of the Society. The first was a notice of intention to have the Society indorse the following resolution:

Resolved, By the Louisiana Engineering Society, that for the purpose of maintaining the high standing of our profession, we hereby condemn any usage or custom by which engineers are invited to enter into competition by submitting bids for the value of their professional services; be it further

Resolved, That, in our opinion, it is the plain duty of all reputable engineers, members of this Society, to refuse, in the future, to enter any such competition.

Mr. Theard's second notice was of intention to change the Constitution as follows:

"To Article II, Section 3, of the Constitution add 'He can be transferred to the grade of member when qualified to become so under Section 2 of this Article.'"

The Secretary was instructed to include the notices in his notice of the next regular meeting of the Society.

Under the head of Technical Exercises, Prof. John M. Ordway read a paper on "Water Supply of the City of New Orleans." It was one of the most valuable papers ever read before the Society. He showed how the deep-dyed artesian well water found at about 700 feet beneath our city, the muddy old Mississippi River water which flows past our doors, and, in fact, any old water, could be made clear and pure by means of settlement, chemicals and filters. The paper was accompanied by ocular demonstrations and experiments, which were edifying and extremely interesting. When the paper and experiments were concluded, a long and instructive discussion followed, and Prof. Ordway was asked many questions.

The vote of thanks from the Society, which Prof. Ordway received, was unanimous.

The meeting adjourned at 10.30 P.M.

GERVAIS LOMBARD, *Secretary.*

APRIL 16, 1900.—A special meeting of the Society to consider the question of legislation was called to order by President Malochee at 8.15 P.M., with the following members present: Theard, Coleman, Woolley, Tutwiler, Wright, Hardee, Stewart, Alfred Raymond and G. Lombard.

Mr. J. F. Coleman read a very concise statement of the present status of the engineer, both professionally and legally, in this State, showing that neither the public nor the profession are in any way protected from malpractice by incompetent engineers, architects, etc. Such malpractice endangered not only the lives and the welfare of the public, but threw dis-

credit and contumely upon the profession, which state of affairs he felt it is the duty of the Society to correct. Considerable discussion followed, and though some expressed the opinion that it was not good policy for the Society, as a Society, to urge any legislation which might be mistaken for selfish or class legislation, it was the consensus of opinion that some relief was necessary, more for the protection of the public than for the profession.

The following resolution was submitted by Mr. Theard and unanimously adopted:

Resolved, That the Legislative Committee be instructed to prepare a written report suggesting such legislation as they deemed necessary and to have printed, if necessary, a notice of intention to apply to the State Legislature, at its coming session, for the passing of an act giving the protection sought. It being understood that this action does not in any way bind the Society, as a Society, to take any further action.

By motion, the Secretary was directed to send out notices for a meeting of the committee on Sunday, April 21, at 11 A.M., to which he was to invite all the members of the Society, requesting them to bring written suggestions, if possible.

Adjourned at 9.05 P.M. GERVAIS LOMBARD, *Secretary.*

Engineers' Club of St. Louis.

506TH MEETING, APRIL 4, 1900.—The meeting was called to order at 8.25 P.M.; President W. S. Chaplin presiding. Thirty-eight members and fourteen visitors were present. The minutes of the 505th meeting were read and approved. The minutes of the 290th meeting of the Executive Committee were read.

The application of J. E. Angell having been recommended by the Executive Committee, he was balloted for and declared elected.

A communication was read from the Washington University Association, announcing a series of lectures on "Chemistry" by Prof. E. H. Keiser, of Washington University.

A recommendation from the Librarian was read and referred to the Executive Committee for action.

The paper of the evening was on "The Commercial Value of Liquid Air," by Mr. Alfred Siebert, refrigerating expert. Mr. Siebert gave a very scientific review of the possibilities and limitations of liquid air. By mathematical demonstration he showed that we may never hope to use liquid air in the manufacture of ice, as the expense of producing one ton of ice would be $40. Although liquid air itself can be produced at fair figures, its application to motive purposes and refrigeration implies such complicated and expensive machinery that its commercial use in these lines is limited. The complication of machinery is necessary because of such high pressures as 2500 pounds, produced by a series of compressions followed by a cooling after each stage. The two types of machines for producing liquid air are those employed by Linde and Tripler, all others being modifications of one or the other form. Prof. Linde uses two compressors and a regenerator, with three distinct coils concentrically arranged. Tripler's arrangement consists of three compressors and one regenerator, with two

concentric coils. At high pressure only 22 per cent. of the total amount of air handled can be reduced to liquid form, and if produced at atmospheric pressure, but 7 per cent. is thus utilized. Above 220° F. liquid air does not exist in fluid form and rapidly vaporizes. Originally, the method of transportation consisted in using a double glass vessel, the air being exhausted from the annular space to form a good non-conductor. The entire vessel was well insulated, and the inner bottle corked with a cotton stopper to act as a safety valve. The liquid was cooled by the heat abstracted when part of it vaporized. Commercially it is impracticable to use glass vessels. Wrought iron cans are made for this purpose consisting of a number of concentric vessels insulated from each other by felt and a small annular air space. The inner vessel contains the liquid, and the concentric shells are so constructed that communication is had from the inner vessel to the atmosphere, making it possible to keep the liquid air under atmospheric pressure, and utilizing the evaporation and circulation through the surrounding cylinders to keep the inner vessel at a very low temperature. Such vessels, however, lose 4 per cent. per hour of their charge, which appears necessary to preserve the remainder, thus accounting for the carelessness which might be wrongly attributed to the express companies in handling the article during transportation.

The discussion following was participated in by Messrs. Nipher, Kinealy and Siebert.

Prof. Nipher gave an interesting blackboard demonstration of the critical points traced on a surface expressing volumes, pressures and temperatures with reference to gases and their transformations.

The Club adjourned to the adjoining room for a light lunch.

F. E. Bausch, *Secretary.*

Detroit Engineering Society.

At a meeting of the Executive Committee at the office of Mr. G. Y. Wisner, at 5 P.M., April 10, the menu proposed by the Secretary was accepted as per copy attached, and the Secretary was directed to make a contract with the Hotel Ste. Claire as per schedule of prices attached.

Secretary reported cash on hand, $276; bills payable, $87.78; leaving a net balance in cash assets of $188.30.

The Secretary reported eight members in arrears for dues for two years, total amounting to $80; fifteen members in arrears for dues for one year, total amounting to $71.50. Secretary was directed to write all those in arrears for dues, requesting payment of same at the time when bills for 1900 and 1901 are issued.

The following bills were audited and ordered paid:

Richmond & Backus Co., printing	$1.00
" " " " "	1.75
Association of Engineering Societies, first quarterly assessment	48.50
Field & Hinchman, postal cards	2.20
" " " " "	1.00
T. H. Hinchman, Jr., Secretary's salary, four months	33.33

The Secretary was directed to invite Col. C. W. Raymond, Mr. F. Hodgman and Mr. H. E. Riggs to be present at the coming banquet of the Society.

The Secretary was directed to acknowledge, with thanks, the copies of the *Railway Review* offered by the publishers, and also copies of the various reports and papers presented by Mr. George W. Rafter. Messrs. E. H. Wheeler and H. L. Woolfenden were passed for membership by the Executive Committee.

T. H. Hinchman, Jr., *Secretary.*

The 48th regular meeting and the 6th annual banquet of the Detroit Engineering Society was held at the Hotel St. Claire, April 20, 1900, at 8.00 P.M., the business meeting preceding the banquet. Messrs. E. S. Wheeler and H. L. Woolfenden were elected to membership. The reports of the Secretary and Treasurer were received and approved.

The officers for the ensuing year were elected as follows:

President—Alexander Dow.

First Vice-President—Willard Pope.

Second Vice-President—E. E. Haskell.

Secretary and Treasurer—T. H. Hinchman, Jr.

The following gentlemen were present at the banquet; President Keep acting as toastmaster: Messrs. Keep, Dow, Haskell, Williams, Sabin, Colburn, Conant, Whitaker, Hubbell, Russell, McMath, Brinkerhoff, Pettee, Porter, Colby, Robinson, Vantuyl, Field, Collamore, Fenkell, Little, Hinchman, Dierkes, Bigler, E. E. Williams, King, Rathbone, Scott, Calder, Demrick, Reid, McCrickett, Woodard, Raymond, Howell, Mattsson, Molitor, Wheeler and Wisner. Messrs. Rathbone and Howell were guests.

The following gentlemen replied to toasts: E. S. Wheeler, "Destruction of the Harbor at Greytown"; G. S. Williams, "The Engineer and the Engineering Society"; W. S. Russell, "The Unknown Quantity"; H. G. Field, "Expansion"; W. H. Pettee, "The University of Michigan."

The meeting adjourned at 11.30.

T. H. Hinchman, Jr., *Secretary.*

Engineers' Club of Cincinnati.

113th Regular Meeting, Cincinnati, Ohio, March 15, 1900.—Dinner was served at 6.15 P.M. The regular meeting was called to order at 7.15 P.M.; with President Punshon in the chair, and fourteen members present.

Minutes of the meeting of February 15 were read and approved.

The Secretary read extracts from a very interesting letter from Mr. W. B. Ruggles, one of the members of the Club, to Mr. R. L. Read. Mr. Ruggles is at present connected with the United States Government work at Matanzas, Cuba, and his letter contained information in reference to the work of improvement being carried on at that place.

Mr. R. H. Warder read the paper for the evening, on the subject "The Establishment of Public Comfort Stations, Lavatories, Small Parks, etc.," which are being introduced in other large cities, both of this and other countries. The paper made suggestions for such conveniences and improvements within the city. He suggested how and where these might be located and established, and pointed out the many advantages they would offer. Quite an interest was manifested in the subject, and a number of the members shared in discussing the matter and aided with plans outlined in the paper.

J. F. Wilson, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, APRIL 6, 1900.—Regular meeting called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved.

The following applications were made and referred to the Executive Committee for approval: For membership—Benjamin C. Donham, civil engineer, of San Francisco; proposed by C. E. Grunsky, G. W. Percy and Adolf Lietz. For associate membership—Richard McCann, builder, of San Francisco; proposed by A. Ballantyne, G. W. Percy and Otto von Geldern.

President Percy read a paper entitled "The Cement Age," giving a brief history of the origin, development, manufacture and uses of hydraulic cement, which was followed by an interesting discussion.

Adjourned.

OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., APRIL 2, 1900.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Ten members present. Minutes of previous meeting read and approved.

Mr. William Danforth was elected to membership.

Mr. Oscar Claussen opened a discussion on "Municipal Lighting" by presenting a comparative statement in detail of the cost of maintenance of the plants at Chicago, Detroit, Allegheny City and the probable cost for St. Paul, having first in a general way outlined the various systems and recent improvements.

C. L. ANNAN, *Secretary.*

Association of Engineering Societies.

Vol. XXIV. MAY, 1900. No. 5.

PROCEEDINGS.

Engineers' Society of Western New York.

Buffalo, N. Y., May 7, 1900.—Meeting called to order at 8.20 p.m.; Mr. Haven, President, in the chair.

The following members present: Messrs. Haven, Foster, Fruauff, Bardol, Morse, Buttolph, March, Symons, Tench, Kielland, Ricker, Cornell, Diehl, Guthrie, Powell, Knapp, Tresise, Tutton, Knighton, Rathman, Rogers Sikes, and several visitors.

Mr. Tutton moved that the reading of the minutes of the last regular meeting be dispensed with, and that the minutes stand approved as printed. Seconded by Mr. Guthrie. Carried.

Mr. Morse moved that the order of business be suspended for the purpose of taking up the literary exercises of the evening. Seconded by Mr. Foster. Carried.

Dr. T. J. Martin was introduced to the Society by Mr. Haven, and made an address on automobiles.

Mr. Thomas McKeown, Mem. A. S. C. E., discussed the subject of siphons as applied to the problem of the Hamburg Canal.

A unanimous vote of thanks of the Society was extended to Mr. McKeown for his able address on the subject of siphons.

Major Symons.—The General Government is going to get up as many engineering models, maps, figures, etc., as it can for an engineering exhibit at the Pan-American Exposition in this city in 1901. It occurs to me that it would be well to have the different engineering societies in the country interested in the matter, because in this way a better exhibit could be obtained. This Society should work in connection with the Pan-American officials, the American Society, the Mining Engineers, Mechanical Engineers. So far as the expense is concerned, I think the Pan-American officials will be willing to take care of that.

Mr. Haven.—I certainly agree with our honorary member that this Society ought to do something.

Mr. Guthrie moved that the Executive Committee be requested to take up this question in its entirety, and to take such steps as may to them seem wise, and report at the next meeting.

Seconded by Mr. Bardol.

Mr. Morse.—I would move, as an amendment to Mr. Guthrie's motion, that a special committee of three be appointed to consider the question and report at the next meeting.

Mr. Guthrie.—I accept that as an amendment.

Motion as amended seconded by Mr. Knapp. Carried.

The President appointed the following committee: Thomas W. Symons, Edmund B. Guthrie and E. C. Lufkin.

Mr. Guthrie.—I had a letter from Mr. Green, of the Cleveland Society, stating that they were coming to Niagara Falls on Decoration Day, and asked for information regarding places to visit, and I immediately wrote back to him that it seemed to me they could better spend a day or two in Buffalo visiting the manufacturing concerns and public works. I bring the matter to the attention of the Society to see if they consider it proper to do anything. I think this Society should visit places about Buffalo, and our own harbor works.

Mr. Ricker.—I would move that a committee of three be appointed to make arrangements for the visit of the Cleveland Society on May 30.

Seconded by Mr. Knapp. Carried.

The Chair appointed the following gentlemen as that committee: Messrs. Ricker, Guthrie and Tench.

The following report was then read by the Secretary:

Buffalo, N. Y., May 7, 1900.

Engineers' Society of Western New York:

Gentlemen:—Your committee of five, appointed at the regular meeting January 8, 1900, "to draft amendments to the Constitution and By-laws, and report at the regular May meeting of the Society," report as follows, viz:

"They have had one meeting, at which four members were present, and the Chairman was directed to proceed and get up a Constitution and By-laws to take the place of the present one. In accordance therewith he read the Constitution and By-laws of about a dozen similar societies, and by means of scissors and paste prepared something for this Society. This he has submitted to each of the other members of the committee in turn, and they have approved the same, with the exception of a few verbal changes which he has made. The committee, therefore, unanimously submit for your action a Constitution and By-laws, which the Secretary will now read."

W. A. Haven,
Chas. H. Tutton,
C. M. Morse,
Douglass Cornell,
F. N. Speyer.

The Constitution and By-laws were then read by the Secretary.

Mr. Guthrie.—I would move that the Constitution and By-laws as read be proposed as amendments.

Seconded by Mr. Knapp. Carried unanimously.

The President said that two copies of the proposed Constitution and By-laws would be in the room of the Society, 975 Ellicott Square, and all members were requested to read them so as to vote intelligently at the meeting on June 4, when final action will be taken.

On motion of Mr. Morse, the meeting adjourned, at 10.50 p.m.

Engineers' Club of St. Louis.

508TH MEETING, MAY 2, 1900.—The meeting was called to order at 8.15 P.M.; President W. S. Chaplin presiding. Twenty-six members and nine visitors were present. The minutes of the 507th meeting were read and approved. The minutes of the 292d meeting of the Executive Committee were read.

The application of Harold A. Rohrich having been recommended by the Executive Committee, he was balloted for and declared elected.

The Special Committee on Rules for the award of an annual prize for the best paper made its report, which, after some discussion, participated in by a number of members, was adopted in its entirety.

The Executive Committee announced its acceptance of the invitation from the Office Men's Club to hold its second meeting in May at their new quarters, the subject of the meeting to be a "Discussion of the Question of Water Filtration." It was decided to invite the Office Men's Club in return for their invitation. It was also moved and carried that the Citizens' Committee, composed of representatives chosen from the various commercial clubs, be invited to this meeting, and participate in the discussion.

Communications were received from the President and Secretary of the Civil Engineers' Society of France, inviting the appointment of four delegates from the Engineers' Club to attend the reunion of the Technical and Learned Societies to be held in Paris from June 15 to 20, on the occasion of the World's Fair, 1900. The Chair appointed the four members of the Club, who will fortunately attend the Paris Exposition, delegates to the convention. The four appointments go to Messrs. J. A. Ockerson, G. R. Olshausen, Richard McCulloch and Alwin Hofmann.

The subject of the evening was a paper on "Some Recent Advances in the Construction and Use of Static Alternating Current Transformers," by W. A. Layman.

The speaker divided all static alternating current transformers into three classes,—viz: First, the "Constant Potential," the function of which is to transform a given alternating pressure of a constant value into another also of constant value. Second, the "Series Transformers," used to derive one current from another, the ratio between the two remaining practically constant, although the absolute values of each vary through wide limits. The third type, the "Constant Current Transformer," the application of which is to supply a secondary current, irrespective of the primary pressure.

About 90 per cent. of all static transformers in commercial service belong to the "Constant Potential Type." The largest units ever manufactured were those recently installed for the delivery of electric current from the Niagara Fall generating station to the calcium carbide furnaces of the Union Carbide Company. The installation exemplified three distinct types of manufacture performing the following functions:

The first set, built by the Westinghouse Electric and Manufacturing Company, raises the 2000-volt current generated in the Niagara Falls station to a transmission pressure of 10,000 volts, the transformation being made from two-phase dynamo currents into three-phase transmission currents.

The second set, installed by the General Electric Company, located in a sub-station, at the Union Carbide Company's plant, two miles distant from the generating station, transforms the 10,000-volt current from the transmis-

sion line and reduces it to a pressure of 2000 volts, at which pressure all current is delivered to the Union Carbide Company.

The third set, built by the Wagner Electric Manufacturing Company, consists of seven (7) units, each of 1500 K. W. capacity. These units reduce the 2000-volt current received from the General Electric Company's transformers to 110 volts, the pressure required at the furnaces. The complete equipment therefore transforms 15,000 H. P. of energy by three operations. An account of the efficiencies of the various transformers was given, and the paper throughout was illustrated by a number of slides.

The meeting adjourned to an adjoining room, where lunch was served.

F. E. BAUSCH, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., APRIL 18, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President Alexis H. French in the chair. Forty-eight members and visitors present.

The record of the annual meeting and that of the special meeting of April 4 were read and approved.

Messrs. Thomas Clark Atwood and George Whiting Wood were elected members of the Society.

The Secretary reported for the Board of Government that it had voted to continue the same special committees as last year, and had selected the membership thereof as follows:

Committee on Quarters—Desmond FitzGerald, E. W. Howe, C. F. Allen, E. W. Bowditch and H. Bissell.

Committee on the Library—L. F. Cutter, F. P. McKibben, F. H. Fay, A. D. Flinn and H. F. Bryant.

Committee on Excursions—A. B. Corthell, C. W. Sherman, D. L. Turner, Sidney Hosmer and J. R. Burke.

The thanks of the Society were voted to the Boston Pneumatic Transit Company, to the Superintendent of Mails, Boston Post Office, and to Messrs. Westinghouse, Church, Kerr & Company, for courtesies shown the members on the occasion of the visit this afternoon to the Union Station and the Post Office, to examine the pneumatic carrier system.

Mr. Leonard Metcalf then read the paper of the evening, entitled "Difficulties Encountered in Building the Storage Well for the Concord, Mass., Sewerage System." The paper was fully illustrated by lantern views. In the discussion which followed, Messrs. F. L. Fuller, F. P. Stearns, F. C. Coffin and L. A. Taylor participated. Mr. Stearns also discussed the well which has been built at Clinton by the Metropolitan Water Board.

Adjourned. S. E. TINKHAM, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., MAY 7, 1900.—A regular meeting of the Civil Engineers' Society of St. Paul was held at the Windsor Hotel at 6 P.M. Dinner over, President Powell called the members to order, and Mr. Geo. L. Wilson read a paper on "Paving Brick," after which the nine members present discussed pavements in general.

C. L. ANNAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, MAY 4, 1900.—Called to order at 8.30 P.M., by President Percy.

The minutes of the last regular meeting were read and approved.

The following were elected to membership upon a count of ballots:

Benjamin C. Donham, civil engineer, to resident membership, and Richard McCann, builder, to associate membership.

The following names were proposed:

For members—Stetson G. Hindes, civil engineer, of San Francisco. Proposed by John Richards, Carl Uhlig, Thos. Morrin and Otto von Geldern. Charles H. Davis, consulting engineer, of New York; references to be furnished.

Mr. Percy opened a discussion on the subject of the obstruction of sidewalks, which was taken up by a number of those present.

The Secretary referred to the recent explosion of Shag Rock in San Francisco harbor, explaining in general terms the methods applied, and stating the results of the blast as far as known.

Adjourned.

OTTO VON GELDERN, *Secretary.*

Engineers' Club of Cincinnati.

114TH REGULAR MEETING, CINCINNATI, OHIO, APRIL 19, 1900.—Dinner was served at 6.20 P.M.

The regular meeting was called to order at 7.45 P.M.; with President Punshon in the chair and seventeen members present.

Minutes of the meeting of March 15 were read and approved.

The Secretary called attention to the fact that the lease of the rooms occupied for meeting rooms would expire with the end of the year, and that the matter of renewing the lease or making other arrangements would soon require attention. Referred to the Executive Board.

Professor Ward Baldwin read the paper for the evening on "The Construction of the Sængerfest Building at Cincinnati."

The roof trusses of the building as originally constructed each consisted of two parallel timber arch ribs braced with iron rods and wooden struts. The ribs were composed of 1 x 10-inch boards 16 feet long, nailed together with 10d. nails, the thickness of ribs varying from 8 to 18 inches. The ribs were supported by eighteen posts, ten of which were 12 x 12 inches, and eight were 12 x 18 inches, built up of 3 x 12-inch planks, bolted together with ¾-inch bolts spaced about 30 inches on centers.

The part of the building under the main roof was oval in plan, being 138 x 194 feet. In the middle were three main arches of 138 feet span, spaced 28 feet on centers. These three main arches collapsed on May 10, 1899, while the building was under construction, and as the first concert was to be held on June 28 not much time was allowed in which to decide what to do. Professor Baldwin was put in charge with instructions to spare no expense to make the building safe, and have it completed in time.

The arches were found to be so badly wrecked that it was decided not to attempt to repair them, but to substitute an entirely new plan of construction. This was done by making the new arches spring from the masonry

pedestals that formed the foundations for the main supporting posts of the old arches. The outer ribs consist of the main supporting posts to a height of 68 feet above datum, and a curved rib with a radius of 97 feet 6 inches. The inner rib is a broken inclined line to a height of 45 feet 10 inches above datum, continued by a curve of 48 feet radius, compounded with a curve of 69 feet radius to the crown. The ribs are 6 feet between centers at the crown, 16 feet 8 inches at the hips, and meet at the pedestal. The ribs are built up of 2 x 14-inch yellow pine boards, and vary in thickness from 12 x 14 inches to 14 x 20 inches. The bracing is of the Howe truss style, and the construction forms practically a three-hinged arch. Two steel girders 4 feet 2 inches high, 10 feet apart, 53 feet 4 inches long, terminating in semicircular girders of 5 feet radius, transmit the thrust between the two groups of end arches.

Many other improvements and changes were made in the construction of the building, and by the energy of all engaged on the work, and a large force of men, the building was just finished in time to hold the first concert on June 29, one day later than originally intended.

J. F. WILSON, *Secretary.*

Detroit Engineering Society.

THE 49th regular meeting of the Detroit Engineering Society was held at the Hotel Ste. Claire, May 18, 1900, at 8 P.M. Messrs. John A. Rathbone and Ernest Lunn were elected to membership, and Messrs. E. Cederstrom, of the Riverside Iron Works, and R. B. Green, of the Solvay Process Company, were proposed for membership.

The papers of the evening were "A Study in Hydraulics," by G. H. Fenkell, and "Water Consumption and Water Meters," by C. W. Hubbell. The papers were generally discussed.

Adjourned at 11.30 P.M. T. H. HINCHMAN, JR., *Secretary.*

AT a meeting of the Executive Committee, held at 7.30 P.M. at the Hotel Ste. Claire, at which were present the President and the Secretary, the following bills were audited:

Association of Engineering Societies	$49.00
Field & Hinchman	9.05

The resignation of W. D. Steele and S. H. Woodard was accepted. The names of Messrs. John A. Rathbone and Ernest Lunn were passed by the committee.

Adjourned at 8 P.M. T. H. HINCHMAN, JR., *Secretary.*

Montana Society of Engineers.

A REGULAR meeting of the Society was held in its new headquarters, Rooms 16 and 17 Tuttle Block, on May 12, at 8.30 P.M.

President Blackford presided, and the following members were present: Messrs. Macdonald, Hobart, Tower, Flood, Fitch, Page, Wilson, Vail and McArthur, of Butte, and Mr. Geo. T. Wickes, of Helena. Three visitors were present.

The Secretary was instructed to tender the thanks of the Society to Hon Mayor and City Council, and the Board of Library Trustees for the use of the Art Room in Library Building for meetings during the past year.

The feature of the evening was the discussion on "The Relation of the Mining Engineer to Mining Litigation."

Mr. Geo. T. Wickes opened the discussion on the subject, which he treated in an able manner. The other members who spoke were Messrs. Wilson, Macdonald, Tower, Page and Vail. The visitors being called upon, Mr. John W. Cotter responded in a neat speech.

Adjourned. R. A. McArthur, *Secretary.*

Association of Engineering Societies.

Vol. XXIV. JUNE, 1900. No. 6.

PROCEEDINGS.

Engineers' Club of Cincinnati.

115th Regular Meeting, Cincinnati, Ohio, May 17, 1900.—Dinner was served at 6.30 p.m. The regular meeting was called to order at 7.20 p.m.; with President Punshon in the chair and thirteen members and three visitors present.

Minutes of the meeting of April 19th were read and approved.

Application for active membership was presented by Frank S. Mitchell, engineer for R. M. Quigley & Co., contractors for the construction of settling reservoirs at California, Ohio, for the water works for the city of Cincinnati.

Mr. J. H. Hilton, chief engineer for the Bracket Bridge Co., entertained the club with a description of the "Construction and Erection of the Steel Wire Cables for a Suspension Bridge over the Ohio River at Rochester, Pa." The bridge referred to is a highway bridge over the Ohio River between Rochester and Monaca, Pa., about twenty miles below Pittsburg. The main span is 800 feet long between towers; the back span on the Monaca side being 400 feet long from the tower to the anchorage, and the back span on the Rochester side 400 feet long to a steel bent supporting the cable and one end of a truss span, at the same elevation as the anchorage on the Monaca side, and from the steel tower to the anchorage about 260 feet, making the total length between anchorage pins about 1865 feet and the cables about 1900 feet long. They are composed of seven strands each, each strand having 288 wires and being about 2½ inches in diameter, making the finished diameter about 7 inches.

Mr. Hilton, who was charged with the erection of the cables by the bridge company which he represented and which had the contract for the erection of the entire superstructure, had never had any experience in that line and undertook the work with some misgivings as to his ability to execute it. However, after studying the subject carefully, he laid out a plan of operations which he carried out successfully and had the cables in place in about four months after beginning work.

Briefly the operation was as follows: He found the wire for the cables in coils on cars near the site of the work, and his first move was to get it unloaded and build a shed for a workshop at a point back from the river on the Monaca side a distance from the tower about equal to the length of the cables. The wire was then reeled onto six large drums holding about fifteen coils

each, in his workshop, the end of the wire of one coil being brazed to the end in the next coil, which was done by notching the ends, lapping them about an inch, with a strip of copper between them, and heating in a portable furnace until the copper melted and fused with the wire.

The strands for the cables were constructed on the ground, which happened to be a level street leading to the bridge. Before beginning the work of making the strands a single wire was placed in the position on the towers which the cables would occupy in the structure, and allowed to take its natural position. Points were marked on this wire for the ends and where it crossed the towers, after which it was hauled back and used as a guide wire by which the length of all others was obtained. Suitable supports were placed in the ground at intervals of about 50 feet, on which the strands rested during construction. Each strand virtually consisted of a single wire, the wire being drawn off the drums and looped over a pin at either end, the required tension being secured by a "tension space" where the wires each sagged the proper amount. An "erection cable" was placed in position a short distance above the location for the cables, resting on temporary wooden towers placed on top of the permanent steel towers, and the strands drawn over into place, suspended from trolleys running on the erection cable, and connected to the anchorage pins at each end. When the strands were all in position and the binding wires removed the individual wires fell into place quite accurately, after which the cables were wrapped around with wire in the usual manner by a special machine designed and furnished by the company that rolled the wire.

Mr. Hilton's description, which was mostly extempore, was followed by an interesting discussion of the subject.

On motion, the club adjourned. J. F. WILSON, *Secretary.*

Engineers' Society of Western New York.

REGULAR MEETING, JUNE 4, 1900.—The meeting was called to order at 8.30 P.M., in the Society rooms, 975 Ellicott Square, by the President. The following named members were present:

Messrs. Haven, Diehl, Tutton, Vanderhoek, Sikes, Guthrie, Speyer, Hoffman, Kielland, Wilson, Buttolph, Ricker and several visitors.

The proceedings of the last regular meeting were approved as printed.

The President announced that the Society had by ballot unanimously elected Mr. Cal Rushton Manbert as a member. The President called the attention of the Society to the black-line process of Mr. Le Clère, of Philadelphia, for reproducing drawings from tracings, specimens of which were hung on the walls of the room. Remarks were made as to the clearness of these prints and their superiority in all ways to blue prints, especially in legal proceedings.

A paper, entitled "The Water Power at Holyoke, Mass.," prepared by Mr. Horatio A. Foster, a member of the Society, was presented, together with wood cuts and other illustrations, but as Mr. Foster was unable to be present at the meeting, the paper was received and read by title only, and ordered to be printed in the JOURNAL, so that it could be taken up and discussed at a future meeting when Mr. Foster would be present.

Mr. Hoffman presented the Society a boxful of beautiful specimens of zinc and lead ores, which he had recently obtained at Joplin, Mo., and he in-

structed the Society in a general way about the ore formations in that district. On motion of Mr. Diehl, seconded by Mr. Guthrie, the Society unanimously voted to thank Mr. Hoffman for his kindness in presenting the specimens and for his explanation of the mining industry of Joplin. The ores were received and placed in the cabinet of the Society.

Mr. Guthrie, of the Committee on the Pan-American Exhibit, then made a "progress report," saying that the committee had had a meeting and discussed the matter with Mr. Buchanan, Director-General of the Pan-American Exposition Company, who was quite enthusiastic over the project, and as a consequence of that meeting the committee had sent out letters through the Pan-American Company to about thirty societies, but that they were unable to get the address of any societies in Mexico, Central or South America. (If any members of the Society know of such addresses the committee would be pleased to have them send such to Mr. E. B. Guthrie, 836 Ellicott Square.) That owing to the short time since the date of the appointment of the committee only a few replies had been received promising co-operation, but replies had been received from others expressing enthusiasm and willingness to act as soon as the various Societies met. It was voted that the committee should be continued and to report, if necessary, during the summer months, to the Executive Committee.

G. C. DIEHL, *Secretary*.

Engineers' Club of St. Louis.

ST. LOUIS, MO., MAY 16, 1900.—The meeting was called to order at 8.30 P.M. at the Office Men's Club, 3022 Olive street; President W. S. Chaplin presiding. Nineteen members and fourteen visitors were present. The minutes of the 508th meeting were read and approved. The minutes of the 293d meeting of the Executive Committee were read.

The Office Men's Club had invited the Engineers' Club to hold this meeting at their new quarters. The Engineers' Club invited all the representative Committees on Water Filtration chosen by the various commercial clubs to be present and participate in the general discussion of the question of "Water Filtration." Unfortunately, owing to a rainy evening, and the condition of the railway accommodations, not so large a representation was had as might have been expected under favorable circumstances. Two of the Engineers' Club members of the Committee on Water Filtration were absent from the city, so that the responsible duty fell upon Prof. Van Ornum, the third member, to lead the discussion. The speaker reviewed the entire history of the movement, which originated with the Engineers' Club, and had been ably supported by all the important commercial clubs. He followed the efforts of its introduction into the Municipal Assembly, and the defeat of the bill providing for an appropriation to erect an experimental plant.

Mr. Colby very ably presented the need and importance of immediate action in the matter of filtration.

Dr. Homan and Mr. Tully, of the Architects' Club, also voiced strong sentiments in favor of such measures as would lead to a proper purification of our water. Dr. Homan, by way of comparison, stated that typhoid fever during the month of April had increased eleven-fold over the corresponding month last year.

Mr. Russell gave a detailed description of the various kinds of filters, the difficulties encountered by other large cities and the uncertainties met with

in treating different waters, making it highly advisable to install an experimental plant in order to determine the most efficient method of handling the water. It was estimated that the cost of a filtration plant for our city would be between $5,000,000 and $6,000,000, so that a sum of $50,000 for an experimental plant would be well expended.

The members from the Wednesday Club were all present and were not backward in expressing their views. As no formal report from our committee was expected, the meeting adjourned.

F. E. BAUSCH, *Secretary.*

Civil Engineers' Club of Cleveland.

A REGULAR meeting was held May 8; President Hopkinson in the chair. Present, twenty-nine members and fourteen visitors. Minutes of April meetings read and approved. Mr. Charles Blackwell was elected to active membership. Messrs. Leon J. LePontois and Wm. E. Reed appointed delegates to represent the Club at Paris Exposition.

Messrs. J. L. Culley, F. C. Osborn and A. A. Skeels appointed as a Membership Committee for the year.

Mr. Charles H. Wright, member of the Club, read a paper entitled "Trusts and their Relation to the Engineer."

Discussed by Messrs. C. H. Benjamin, Wm. H. Searles, A. E. Brown, W. L. Cowles, E. E. Boalt, C. H. Wright, F. C. Osborn and C. W. Hopkinson.

Adjourned 9.40 P.M. to light lunch served in Club rooms.

ARTHUR A. SKEELS, *Secretary.*

A SEMI-MONTHLY meeting was held May 22; President Hopkinson in the chair. Present, twenty-six members and thirteen visitors. After a short discussion upon "Excursion to Niagara Falls" it was moved by Prof. C. H. Benjamin, Mr. C. O. Palmer second, that the matter be left to the individual members to act as they saw fit. Carried.

Mr. Wm. B. Hanlon then read the paper of the evening, entitled "The Mining and Handling of Coal."

The paper was illustrated with slides.

Discussed by Messrs. A. H. Porter, Wm. B. Hanlon, H. L. Olmstead, C. W. Hopkinson, C. O. Palmer, W. B. Bogardus, W. O. Henderer, W. H. Burns and Wm. H. Searles.

Adjourned 9.50 P.M. to light lunch served in Club rooms.

ARTHUR A. SKEELS, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, JUNE 1, 1900.—Called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved. The following were elected to membership upon a count of ballots: Stetson G. Hindes, civil engineer, San Francisco; Charles H. Davis, civil engineer, New York.

A letter was read from the Committee of the Engineers' Society of Western New York, calling attention to the proposed Pan-American Ex-

position, to be held in Buffalo in 1901, and inviting this Society to participate in whatever engineering or technical feature may be proposed or carried out on such an occasion.

The communication was referred to the Executive Committee for an action thereon.

Mr. Edgar Kidwell, Ph.D., addressed the Society on the subject of "Built-up Wooden Beams," illustrating his address with lantern slides prepared for the purpose. A discussion followed.

Upon motion, a vote of thanks was passed for Dr. Kidwell for his courtesy in preparing his interesting data for the Society.

Adjourned.

OTTO VON GELDERN, *Secretary.*

JOURNAL

OF THE

Association of Engineering Societies.

BOSTON. CLEVELAND. MINNEAPOLIS. LOUISIANA.
MONTANA. ST. PAUL. BUFFALO. CINCINNATI.
DETROIT. PACIFIC COAST. ST. LOUIS.

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AUTOMOBILE VEHICLES.

BY PROF. LOUIS DERR, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

[Read before the Boston Society of Civil Engineers May 16, 1900.*]

FIVE years ago there were not thirty practicable automobile vehicles in the world, and three years ago this number would have covered those in the United States. Up to September 1, 1899, the capitalization of companies formed for manufacturing automobiles was $406,945,000, not including an additional million for the manufacture of specialties or for operating. A great industry has been created out of nothing, resembling in rapidity of growth the electric railway, and without a doubt destined to exert as important an influence on transportation interests.

The problem confronting the automobile builder is to apply to the frame of a road vehicle a motor of sufficient power and endurance, under absolute and quick control and free from liability to accident or failure. It should be simple, easy of repair and capable of satisfactory operation without technical training on the part of the driver. Renewals of energy should be readily obtainable, and at a moderate cost. But the attempt to solve, even approximately, the problem stated in these requirements is a matter of extreme difficulty, and a complete solution cannot yet fairly be said to have been found. The problem has been approached from a number of sides, and the purpose of this paper is to present a brief discussion of the various methods by which vehicles of the present moment are propelled.

Existing types of motive power may be classified as follows:

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steam engine. The shock accompanying the explosion requires a more substantial construction than would otherwise be necessary, and the high speed at which such motors must be run to develop sufficient power in small weights renders careful balancing imperative to prevent excessive vibration. In small sizes the cylinder may be kept sufficiently cool by providing it with projecting ribs to increase its radiating surface (see Fig. 2), but in engines of over 4 horse power a water jacket is necessary. The water is in turn cooled by circulation through a cooler composed of ribbed tubes and exposed to a draft of air.

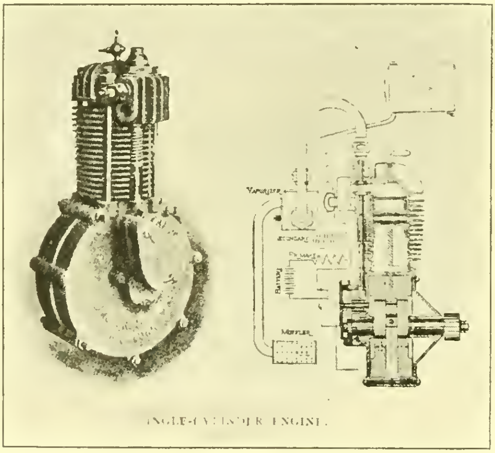

FIG. 2.

The original open-flame method of igniting the charge has been superseded by the hot tube method, and this in turn is being displaced by the electric spark. The former method requires a tube of nickel or other refractory material, closed at the outer end and heated to dull redness by a flame. The open end of the tube communicates with the cylinder, and the heat ignites the compressed charge. This has proved somewhat unreliable, and at present most engines are ignited by an electric spark. This is produced by an induction coil or similar apparatus, the spark points consisting of a pair of platinum wires projecting through an insulating plug into the cylinder.

The objections to the explosion motor for automobile service are its complexity and—thus far at least—its unreliability. The latter is almost wholly due to the ignition apparatus, and it is interesting to note that both methods of ignition are now used on French racing carriages. The motor is not self-starting, and a special

starting gear must be provided. The same is true for changing speeds and backing, both of which are usually accomplished by gear trains, although belt transmission is also used. The vibration of the engine is also a difficulty not easily overcome. Minor causes for criticism are the loud noise of the exhaust, even when a muffler is used, and the odor which is left for some time in the track of the machine. On the other hand, the speed and endurance of vehicles of this type far surpass anything that has as yet been obtained by other constructions, and they are therefore pre-eminently fitted for racing and long runs. A tricycle fitted with a motor of this type (see Fig. 3) has covered 45 miles within the hour, portions of the

Fig. 3.

distance at speeds greater than 60 miles per hour; and the limit seems to be only in the physical endurance of the rider and the heating of the pneumatic tires.

As might be expected from the time during which the steam engine has been a practicable prime mover, the steam-driven automobile has a lengthy history. In 1769 Jean Francis Cugnot built a steam-propelled gun carriage, using an internally fired kettle-shaped boiler and an engine connected to the driving wheels by a ratchet and pawl mechanism. Development was very slow, however, and in England was entirely stopped by restrictive legislation and in America by the absence of good roads. The removal of legislative restraints in the one country and the appearance of satisfactory highways in the other have greatly stimulated invention and the result is a considerable number of steam vehicles both for light and heavy service.

The steam carriage for pleasure may be best discussed by describing a type now extensively exploited in this country (see Fig. 4). This carriage has a small upright fire tube boiler, holding six or seven gallons of water and weighing about 100 pounds. The fuel is gasoline, stored under air pressure in a supply tank. After vaporization by passing through heated tubes it is blown through a burner, taking up in its passage air enough to insure proper combustion. Automatic arrangements shut down the fire when the steam pressure reaches the predetermined limit. The engine is double, of the marine type and is connected to the driving wheels by a chain gear.

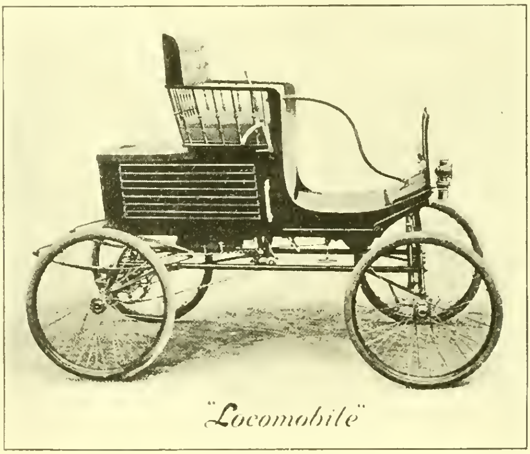

FIG. 4.

The small size of the reciprocating parts renders the engine vibration insignificant, and the carriage makes but little noise. A further advantage is its lightness, a carriage for two persons weighing, when fully equipped, only about 600 pounds. Its endurance depends, of course, on the size of the fuel and water tanks, but may be set as 20 or 30 miles for one filling. The great advantage of motors using naphtha or gasoline over storage batteries is that a new supply requires only a few minutes' time, and is readily obtainable. Low first cost, small operating expense and comparative simplicity of construction are further items that have contributed much to its popularity.

The steam carriage, however, is by no means free from objections. In starting or after long stops time is required to raise steam, and on the road a considerable fire is burning, supplied by the most inflammable fuel under pressure. This is a source of possible

danger that should not be forgotten. The small size of the boiler and its very great steaming capacity make a frequent inspection of the water-glass an essential part of the driver's duties; and in general it may be said that the steam carriage requires more care on the road than any of the types previously described. A minor objection is the visible exhaust in cold weather. Apparatus for condensation, if effective, is too cumbrous to be satisfactory.

The small size and method of construction of the boiler render accident from explosion unlikely, but the water level must be rather closely watched to prevent burning the tubes by the intense fire. A type of boiler is coming into use known as the "flash boiler," in which there is very little water, only as much being injected as is required by the engine, stroke by stroke. This boiler, developed by

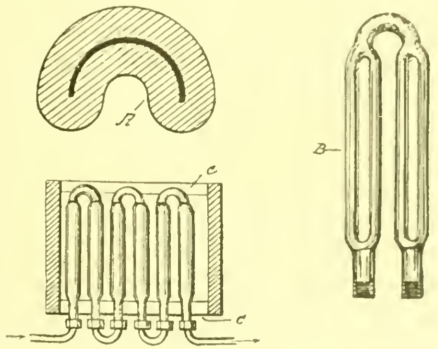

FIG. 5.

Serpollet in France, and commonly known by his name, consists of a series of tubes of very narrow cross-section, heated to a high temperature by the furnace gases. Fig. 5 shows the section and assembly of a Serpollet tube. The tubes vaporize the water almost instantly, and can be heated red hot without injury. It is evident that the water supply must be automatic and exactly proportionate to the consumption of steam. This requires reliable feeding devices. The tubes are short-lived but inexpensive, and their thickness, combined with the small amount of water in the boiler, makes explosion practically impossible.

Compressed air has been the engineer's dream ever since the invention of the steam engine, and many attempts—for the most part futile—have been made to apply it to vehicle propulsion. The chief trouble is from the inevitable refrigeration accompanying expansion, which, without reheating devices, quickly clogs the exhaust passages with frost; but, even apart from this, the energy stored in compressed air is really comparatively small. It can be shown by

a simple calculation that a pound of air, expanding isothermally from 150 pounds gage pressure to 15 (11 atmospheres to 2), will develop 48,300 foot pounds of work. Assuming that the steam carriage already described will develop 2½ horse power hours before exhaustion of water supply, it follows that 103 pounds of air will be needed for the same endurance under the given conditions, which, by the way, are beyond the possibility of realization in practice. At the given pressure the air would occupy 122 cubic feet, and a tank nearly 5 feet cube would be needed. As this is out of the question, a much higher compression is used, and the customary pressure is 2200 pounds, or about 150 atmospheres. This reduces the volume to 9 cubic feet. Steel reservoirs to withstand this pressure weigh about 85 pounds per cubic foot of capacity. A weight of 66 pounds has been realized, but in this case the factor of safety is rather small, and explosion of a tank under this pressure is highly dangerous. Thus to contain the air 765 pounds of reservoir will be needed. To have 165 pounds pressure at the end of the run another pound of air will be required, making a total of 869 pounds for reservoir and contents. This may be instructively compared with the 240 or 250 pounds required by the steam carriage for fuel, water and boiler. The weight of engines and piping is assumed to be the same in the two cases.

In practice the case is not quite as favorable for the air engine. Available data indicate that by using compounding, reheaters, etc., —all adding weight and complication—about 0.27 of a horse-power hour can be obtained from a cubic foot of air at 2000 pounds pressure. This weighs nearly 11 pounds, whence to get 2½ horse-power hours 118 pounds of air will be required. In the table below the available energy of compressed air expanding without loss under different pressure conditions is given for the sake of comparison with other sources of power.

In this connection it may not be out of place to call attention to the ludicrous claims put forward for the energy available when liquid air is vaporized. Of course the only reason for employing liquid air is the fancied possibility it offers of carrying the equivalent of a large amount of gaseous air without pressure. By noting that about 800 volumes of free air are required to produce one volume of liquid air, the energy of a pound of the liquid may be easily calculated. If vaporized in a closed tank the pressure would rise to 800 atmospheres, or, roughly, 12,000 pounds per square inch. Assuming that the total energy can be realized in isothermal expansion, there would still be demanded 10.5 pounds of liquid per horse-power hour, or, in other words, a gallon of liquid air repre-

sents a maximum of only three-quarters of a horse-power hour, an amount by no means difficult of comprehension.

The following table presents at a glance the previous results, and shows clearly the reason for the extraordinary endurance of the internal combustion engine:

	Foot Pounds per Pound of Medium.	Pounds per Horse Power Hour.
Light storage battery	15,000	132
Steam in small engine	49,500	40
Air expanding isothermally from 165 to 30 lbs.	48,300	41
Air expanding isothermally from 165 to 15 lbs.	69,400	28.6
Air expanding isothermally from 2200 to 15 lbs.	137,000	14.4
Air expanding isothermally from 12,000 to 15 lbs.	188,000	10.5
Air in perfect air engine, 165 to 15 lbs.	48,700	40.7
Air in perfect air engine, 165 to 30 lbs.	37,600	52.7
Air in perfect air engine, 2200 to 15 lbs.	74,400	26.8
Coal, 14,500 B. T. U., in steam plant of 12½ per cent. total efficiency	1,410,000	1.40
Kerosene, 20,700 B. T. U., in internal combustion engine of 35 per cent. efficiency	5,590,000	0.354

The question of cost of maintenance, always an interesting one, has not yet been definitely settled for American conditions. The following table is for a carriage belonging to a French physician, and covers an experience of 6000 kilometers (about 4000 miles). It undoubtedly represents a fair average cost. Although in this country the fuel and lubrication cost would probably be smaller, and the writer's experience would incline him to reverse the proportion of repair and depreciation charges, the greater cost of tires for American roads would probably keep the total about the same. Of course, if the carriage is cared for by the owner the last item disappears:

Gasoline	2.00 cents per mile.
Oil and grease	0.15
Tires	0.04
Repairs and miscellaneous	5.05
Depreciation	3.00
Interest and taxes	1.09
Hostler	4.67
	16.00

In conclusion, it may fairly be said that the choice of type depends almost wholly on the character of the service. For urban passenger service, where recharging stations are conveniently accessible and frequent stops are necessary, the electric vehicle will probably hold its present supremacy for some time. For heavy service the steam car seems to be the most successful, and for high speeds and long runs the internal combustion motor at present shows a decided superiority over its less costly rival, the steam engine.

DISCUSSION.

Mr. John Balch Blood.—Liquid air has a latent heat of about 142 British thermal units. The power in steam has a potential energy due to heat difference between itself and the air. The steam has 966 latent heat units, and then we put in about 200 more, depending on the pressure, which makes about 1200. The difference of temperature of liquid air is not more than 300° or 400° below ordinary air. Taking 300 and adding it to 142 we have between 400 and 500. Hence, a pound of liquid air is only about half as good as a pound of steam. Neglecting the friction of the machine, steam compares with liquid air, as a refrigerative agent, in the ratio of about 500 to 1200. In other words, the thermal condition of liquid air is less removed from normal than is that of steam under pressure, in about the ratio of 5 to 12.

Let us look at this now with reference to two aspects,—namely, power and refrigeration.

First, with reference to power, it is evident that, with equal efficiencies of conversion, steam would be 2.4 times as good as liquid air per unit of weight.

The best we can do with steam is to utilize 200 B. T. U. per pound of steam, which would give an efficiency of the steam cycle of about 16 per cent. Therefore, liquid air must have at least 40 per cent. for efficiency of conversion to be on a par with steam.

We do not yet know what efficiency of conversion we do obtain, but, when we realize that we must expand from 12,000 pounds per square inch down to zero, we do not have a very bright outlook.

In New York, on the air power cars, they use 2000 pounds in the receivers and expand through two engines, and even then exhaust under pressure.

If the efficiency of conversion of liquid air were 100 per cent., the power obtainable would be only 2½ times that of steam for a given weight. When you come to compare costs, steam is many times the cheaper, as no one has presumed to quote a price for liquid air that would compare at all with steam. Coal at $4.00 per ton is 5 pounds for one cent. If one pound of coal will evaporate 8 pounds of water we have 40 pounds of steam evaporated for one cent, or one pound of steam would stand at $0.00025.

For power purposes, therefore, if we assume that the conversion from liquid air is perfect (which we know is not a fact), liquid air must be sold at a price less than one mill per pound in order to compete with steam.

So much for the power aspect.

Second, with reference to refrigeration.

We saw above that liquid air had a negative temperature or refrigerative value of about 500 B. T. U. Ice has a latent heat of about 114 and a negative temperature of about 40°, which would give approximately a refrigeration value of 150 B. T. U.

It will be seen that for refrigeration one pound of liquid air is equal to 3.3 pounds of ice. If ice sells for 30 cents per 100 pounds, liquid air must sell at one cent per pound to compete.

Professor Derr.—In regard to compressed air automobiles, there is one industrial or economic consideration which should not be overlooked; that is, the danger, the positive danger, of carrying bottles of gases at a pressure of 2000 pounds to the square inch. I have often been questioned as to the danger to be feared in steam boilers carrying 200 pounds pressure, but no Board of Aldermen has objected to the steel air-bottle, although one of these bottles exploded of late, wrecking a stable and injuring six men rather seriously.

In answer to a question, Prof. Derr said: Heavy trucks, I think, ought to be safe to use. From the showing I tried to make in the table, the battle is going to be fought out between steam and gasoline, and, of course, if it is a question of steam, either some form of stored heat or liquid fuel will be used for urban service. Otherwise, I do not think the steam vehicle will be quite as much in favor as others. The heavy trucks, particularly the English ones, are invariably driven by steam; some of them are operated with solid fuel. The heavy gasoline engine is not yet a success.

The President then called upon Mr. Knight Neftel, manager of the New England Electric Vehicle Transportation Company, who spoke as follows:

Mr. Knight Neftel.—We are operating here and in Chicago, New York, Philadelphia and Washington a very large number of carriage batteries. In some cases we have used these batteries for three and four years, and our experience has been that the battery has given us less trouble and less cost for repairs than any other part. We have numbers of batteries that were installed three or four years ago, and I think the professor was mistaken when he said that there were only thirty automobiles in New York two years ago. We had more than this in operation in New York alone (electric), and these batteries are to-day in use in New York, the replacement of plates being a very small expense. The bad reputation that storage batteries have generally obtained may be explained by the statement that the manufacture of the reliable storage bat-

teries has been confined to one concern; those who have experimented with electric vehicles have not always been in position to obtain this make.

I hardly need say that the gasoline machine is not a vehicle for urban use. It is, as you have seen by the pictures, exceedingly complicated. It does not start easily; furthermore, it has the very great disadvantage of not being able to back unless it has a reversing gear, which is another complication not dwelt upon by Prof. Derr. The driver of an ordinary hack, cab or carriage for the transportation of passengers must be able to start up rapidly, or he will stall traffic. He must have absolute control of the vehicle in the method of starting, and he must also be able to reverse it instantly, if necessary to save life, and he must be able to back out of a tight place.

The electric motor gives, with a man of ordinary intelligence (such as it pays transportation companies to employ), that convenience and ease of operation which no other vehicle can give. Of course, the steam carriage can be reversed, but there are other difficulties with a large-sized steam vehicle which I need not touch upon to-night.

The greatest source of expense and of trouble to the automobile user is the tires; if he has a light vehicle, such as the locomobile, he meets with punctures, as on bicycles; if he has a gasoline vehicle, he wears the tires out; if he has an electric vehicle of greater weight, the tires are liable to explode. You have probably seen or heard these explosions on the streets here. The tire is the expensive part of the machine. The ingenuity of a great many men is engaged in remedying this difficulty, and we hope that some one will soon solve the problem.

The handling of the automobile business as a mercantile affair, with a company such as I am connected with, is a field which promises to be remunerative to capitalists and operators, and ultimately of great benefit to the public. It has required an enormous investment of money, and is still somewhat experimental. It has required the energy of a great many men to solve what may be called a great problem of organization. The handling of two, three or five hundred carriages of the various styles, dimensions, weights and capacities, entirely by mechanical means, and training men to take care of the mechanical system by means of which this is done, and finally the various trials and tribulations on the streets with the authorities and with the public, called for great expenditure of energy and of time by those who have promoted this enterprise in the different cities.

The result of one year's operation in Boston has been as follows: The present plant of our company has been in operation since October 2, so you will see that it is not yet a year old. So far we have traversed the streets of Boston to the extent of 112,000 miles, adding about 2000 or 3000 miles a day to this total. We handle, in storage batteries, from four to five hundred tons every day in our station. We operate about 154 automobile vehicles of various kinds, and we are adding about 60 more to be used for delivery wagon purposes. I am not referring to these things except to show you an interesting mechanical problem which is being worked out in this town, and of which, perhaps, many of you do not know.

For the charging of our batteries and the operation of this plant we are taking 100,000 kilowatt-hours of current per month, and I am happy to say that we are just getting clear of our pay rolls and other expenses. In other words, the service, I think, has proved popular with a great majority. There are some who do not like riding in these cabs, but, so far as we can judge, it is popular.

The delivery wagon part of the business is to me the most interesting, because that is simply a problem in transportation, where the vehicles are not confined to tracks and where we are filling a very large demand. We experimented with this at first, contracting to do the transportation on a limited scale for a large department store; after a short time it proved so successful—to them financially, and to us mechanically—that an arrangement has been made covering a period of years for the entire transportation of their sales.

Another experiment was tried in the delivery of newspapers; this has also proved so successful, so economical and such a saving of time, which is an item of importance to those concerned, that a still larger contract for a greater period has been entered into for the distribution of a large proportion of the newspapers from here to Roslindale and Dedham on the south, and to Lynn and Waltham on the north and west.

Other experiments have been tried here, in Philadelphia, in Washington and in New York, on other types of work of this kind, and in every case this feature has developed: that while there is no economy in supplying a man with one vehicle, there is a very large economy in supplying a man with ten vehicles. I now refer to the user. In other words, one vehicle will not compete with a horse, so far as economy is concerned, but ten vehicles will do the work of fifteen horse teams, not only more rapidly, but more satisfactorily.

It does not pay the small grocer, who has but one wagon, to buy, hire, rent or use an automobile, as one horse will be cheaper. But if he uses ten, twenty, forty or eighty wagons, the economy is very great and immediate.

I have intended to ask some of the engineers of Boston to visit our plant when completed, but we have been very much delayed in its completion. It is interesting and entirely different from anything ever attempted before on such a scale, and if, after the meeting, any of the gentlemen would like to look at some blue prints, showing the method of handling our batteries, I shall be glad to show them, and I hope the Society will accept an invitation and come and see our plant when in full operation.

Mr. Blood.—Mr. Neftel gives 500 tons of batteries for 154 vehicles, that is, two tons of battery handling a vehicle a little less than 20 miles a day; 3000 miles a day for 154 vehicles makes less than 20 miles a day. If the batteries would not do a great deal more than that they would be considered pretty poor batteries.

When you consider repairs on batteries compared with taxes, interest on investment and (in any mercantile enterprise) driver and caretaker, you will find that the depreciation account can be multiplied by four or five before it will come up to the other factors.

Mr. Neftel.—The gentleman is probably not aware that the battery has to be handled three or four times for every trip of the cab, and that the trip may be only a mile. If you will take my figures, 480 to 500 tons, figure out the number of batteries which that represents, and then try to find the mileage from that, you naturally will get extraordinary results. You would also get results which would be astounding if you were to figure how many times you have to handle the coal before it goes into the locomotive furnace, and how many miles this coal is transported before it is utilized, or some other such problem, but the coal has to be handled and so do the batteries.

If you call a cab from the Touraine and want to go to the South Union Station, we probably have to handle that battery four or five times; that is where the problem of mechanical handling comes in.

For pleasure vehicles, altogether a different field, entirely different batteries are constructed, such, for instance, as those used by Mr. Maxim, who made a run from Philadelphia to Atlantic City and return of over 110 miles and could have gone further.

When it comes to commercial, heavy, hard work, you must use low-capacity batteries, very heavy and very durable, and you will get good results. One more remark in reference to weights.

We have records of a large number of different vehicles. We run vehicles which are very light and we have records of mileage and repairs, and our reports are very accurately made daily, not only here, but all over the country. Besides, we operate trucks which will carry two tons at the rate of 10 miles an hour. We have found that the heavier the vehicle, the less are the repairs and the cost of operation, and the greater the durability. This is an actual fact, and I will be pleased to show you how much less it costs us, in repairs and in power, to push one of these Houghton & Dutton wagons, loaded, than it does to push a two-seated carriage. That is a very curious development, and that is the reason why we feel that the question of weight is not of such moment as many would make it. While a very light automobile buggy is the one that will fall apart first, the heavier one with wooden wheels has an excess of weight of material to prevent parts getting out of line, and other troubles, and is the one that will last the longest. A few pounds more or less amount to nothing as far as mileage is concerned.

PROFESSOR ALLEN.—I should like to ask the last speaker how far, for heavy work, he expects a battery to last between reloadings.

MR. NEFTEL.—A battery could not run an ordinary automobile delivery wagon, with a load of one ton, more than 25 miles. Of course, the distance depends greatly upon the road. On a level road, under good conditions, with a standard storage battery, it should not be asked to drive more than 25 miles; one of Houghton & Dutton's vehicles will go 40 miles with two batteries in Boston and suburbs.

Professor Derr was asked whether the statistics he showed on the table, relating to a physician's carriage, referred to a French physician. He answered in the affirmative.

PROFESSOR WATSON.—Suppose we were to take one of our vehicles, I do not mean a city cab, but one of the carriages which would be used in the country, say by a physician down on the cape who would have to go for miles around, or by a farmer who delivers produce, and who goes over country roads which are full of ruts. I always imagined that the natural tendency would be to get them as low as possible for the sake of lightness and cheapness. I suppose the expense for such a carriage would be very large.

PROFESSOR DERR.—I would be glad to furnish figures, but as far as I know none are in existence. If the French automobile estimate of 17 cents per mile is taken for a basis, the expense for such a carriage as the last speaker mentioned would be quite large.

The gentleman who spoke of storage batteries has not proved his case; my own experience is of the same kind. I have operated a steam carriage for 700 miles, at a total cost of repairs of 95 cents. If the cost of battery repairs and renewals can be correctly estimated from data obtained in operating heavy, low-capacity batteries, or even from the general average of a plant less than a year in operation, then it seems to me equally proper to estimate the cost of repairs to a steam carriage, such as the one mentioned, as one-seventh of a cent per mile, and the latter proposition would be quite difficult to establish.

AUTOMOBILES.

By Dr. T. J. Martin.

[Read before the Engineers' Society of Western New York May 7, 1900.*]

Ever since the discovery of steam power there has been a demand for self-propelling vehicles, and the present development can be traced from the road roller and bicycle to the advanced forms used for mercantile and pleasure purposes to-day.

Road motors attracted the attention of inventors as far back as the end of the last century, and in 1801 there was a steam carriage which would climb hills faster than a man could walk. Before inventive attention was turned to railroad development there were many attempts to perfect these road carriages.

From 1825-1835 the Squire carriages were running in England at an average speed of fourteen miles an hour, but these early attempts did not attain the excellence or cheapness necessary to create a demand among the masses for that form of locomotion.

This end of the century is a "rapid" one, and we are a "rapid" people who have created a demand for something not yet entirely developed, although we have three very satisfactory forms of self-propelling vehicles.

We require of the automobile that it be easily controlled, steered and stopped. It must have speed and abundance of power. It must be cleanly and not too noisy.

The real problem is, of course, which is the preferable power, looking at the question as it is developed to-day.

Let us consider the three motive powers in practical use to-day, with their comparative costs of operation, etc.,—viz, electricity, gasoline and steam.

Mr. Riker, in a recent address, gave a concise description of the batteries used in electric vehicles. He said:

"We do not require any change of gearing in the electric automobile to alter the speed or climb a grade, but accomplish this electrically by a series of switches, so grouped as to be operated by one handle, which is called the controller.

"From this controller wires lead to four groups of batteries and to the motor or motors, as the case may be. As the speed of an electric motor depends upon the pressure of the current supplied, you will at once see that change of pressure means also change of speed. This pressure, in technical language, is called *voltage*.

"As it is necessary when recharging the batteries to connect them to a direct current, each cell requiring about 2.5 volts, and as

*Manuscript received June 7, 1900.—Secretary, Ass'n of Eng. Socs.

the prevailing pressure is about 110 volts, it is necessary, if we desire to charge economically, to use from 40 to 44 cells of battery.

"These cells are placed in four crates or boxes, each holding ten cells. The cells in each crate are connected in series; that is to say, the positive terminal of one is fastened to the negative terminal of the next. As the pressure of a cell on this charge is about 2 volts, and there are ten in a crate, the pressure at the terminals of each crate is approximately 20 volts. Now, it is possible so to connect the four boxes that we obtain three pressures,—namely, 20 volts, 40 volts and 80 volts. In the first position the four crates are connected so that the motor receives a pressure of 20 volts. When they are connected in multiple each crate furnishes one-fourth the total current. For example, if the motor takes 20 amperes, each box is furnishing 5. This arrangement allows all of the cells to discharge at the same time. This method of control has another very advantageous feature. If one of the crates, say, for example, No. 2, should show signs of being discharged before the others, we may, by leaving the controller in the first position for a short time, make the other crates charge the weak one, and thus save those cells from overdischarge and possible injury. In the second position of the controller crates 1 and 2 are connected in series, as are also 3 and 4. These two sets are then grouped in multiple, and furnish a pressure of 40 volts to the motor. In this second arrangement only one-half of the total current is supplied from each crate; therefore, if the discharge is as before, 20 amperes, each crate or box is furnishing 10. We now come to position No. 3, which gives the greatest pressure we are able to produce. In this position all the crates are connected in series, and the pressure supplied to the motor is 80 volts,—20 amperes are furnished by each crate.

"As it is necessary to know how much electricity we have stored up, and how fast this is being consumed, we use a combined volt and ampere meter. I think at this point it would be well to explain that the difference in pressure between a fully-charged storage cell and the same discharged is about 0.3 of a volt, being 2 volts at the beginning and 1.7 volts at the end of the discharge. With 40 cells, the pressure at the start is 80 volts, which falls gradually to 68 at the finish. These meters are therefore marked in this manner: Opposite 80 volts the word *charged* is written, and *discharged* against 68. You can therefore spin along at ease until, while running on a level stretch of road at a normal discharge, your meter reads 75 volts. You know then that you have used half your charge, and that you must either return or find some

means of recharging. This device has been in constant use for over three years, and I have never known any one to run out of charge who was governed by the reading of the meter. I have so far explained only one side of the meter, and how it operates on discharge or the running of the carriage. It has still another function. When a storage battery is connected to a source of current to be recharged the back pressure of a cell is about 2.1 volts, making the 40 cells require 84 volts to recharge them. As they absorb the charge, their pressure gradually rises to 2.5 volts per cell, or 100 volts for the 40 cells, at which pressure the charging should be stopped, as the battery is full. The meter also indicates this condition. As it is also necessary to know at what rate to recharge the cells, the other half of the instrument is graded in amperes. This portion of the meter has a double scale, reading either the amount of current going into or out of the battery, enabling us to charge at the proper rate for the best results to the battery, and, when running, shows the amount of power being used. It is therefore possible, with an electric carriage and one of these meters, to know at any time just what horse power you are developing."

Gasoline, four-cycle operation:

"First stroke draws in a charge or mixture of gasoline and air; the next stroke compressing that mixture through a higher atmospheric pressure, varying from 40 to 70 pounds pressure; the next stroke being the useful stroke of the four, in which the charge is exploded and the piston driven forward.

"The fourth cycle is the one in which the exploded gases are expelled from the cylinder, and the cycle commences over again. Therefore, in a single-cylinder gasoline engine we have one useful stroke in four. Multiplying our cylinders, taking two cylinders, we have one useful stroke in each revolution. If we have four cylinders we have two useful strokes in each revolution, if they are properly proportioned and divided."

There are two classes of gasoline motors,—flange cooling and water jackets; vaporization, tank method vaporizer.

The steam carriages best known are the Overman, Crouch, Whitney, Locomobile.

The Overman has a steam boiler and a slide-valve engine. Steam is exhausted into the hollow tubes of the running gear, and passes into the atmosphere through small holes drilled in the front axle.

The Crouch carriage employs superheated steam. All these makes are of the same general kind, using a small boiler which is fired by gasoline.

In the Locomobile gasoline is used as a fuel; the tank is under the footboard. Fuel is forced by compressed air through the boiler, where it is vaporized, to the burner, where it is ignited. The power is obtained by means of a chain from the engine sprocket to the sprocket on the rear axle.

DISCUSSION.

Mr. Guthrie.—Has the weight of the automobile increased or lessened?

Dr. Martin.—It has increased. It has been found, by actual experience throughout this country and Europe, that to obtain satisfactory commercial results all manufacturers were obliged to guard against one common enemy,—namely, crystallization of metal. Automobiles are invariably built for speed. Speed in turn, on the average American roads, means violent vibration. This vibration is intensified at those points about the machine which carry the maximum weight at an angle, such as pivot axle, steering arm, rear axle, near the bearings, etc. All electric machines carry a storage battery varying in weight from 500 to 1800 pounds. The bulk of this weight is in the lead plates. The first carriages built by the Pope Manufacturing Company weighed about 1600 pounds (battery included). This same type of machine (Mark III) to-day weighs nearly 2600 pounds (battery included). The increase in weight is required, first, to meet the demand for increased mileage, and, second, to guard against crystallization. The machine weighing 1600 pounds had a 20-mile maximum capacity. The 2600-pound machine has a 35-mile capacity. A heavier and longer mileage battery requires, in turn, heavier and stronger parts of the machine. I have some very interesting specimens at our station of crystallization at these various points of the machine.

Mr. Guthrie.—Why is the automobile so expensive?

Dr. Martin.—The automobile must be an expensive product as long as it has not become standardized in its various parts. A visit to the motor vehicle factory reveals the fact that every bolt, nut, screw and everything else is turned out by day labor and lathe work; in fact, little is seen of an automobile until the "assembling" and finishing departments are reached.

Mr. Morse.—Which machine is liked the best here?

Dr. Martin.—In foreign countries, such as Germany, France and England, the gasoline machine is the favorite, for two reasons: First, the unlimited mileage permitting longer distances between points where charging stations could be established, and, second, the fact that gasoline is universal and cheap.

Europeans try to get away from the "horse carriage" idea. They demand a veritable machine, and when driving one for pleasure or business they dress accordingly; that is, they wear rubber coats, leather caps and "goggles," thus protecting themselves from grease and dirt. They go into it from a sporting standpoint.

In this country, where the art of manufacturing and running motor vehicles is comparatively new, the electric machine has the preference, because it is noiseless, clean, odorless and does not require a machinist to operate it successfully. The ease with which electricity can be obtained in almost any village is another point in its favor.

Mr. Guthrie.—What is the cost of maintenance?

Dr. Martin.—Permit me to use my own Columbia carriage (Mark III, Lot II) as an illustration. I have operated this carriage in this city for the past three winters and two summers, covering about 35,000 miles. It has never cost me over three-fourths of a cent per mile for current. The cleansing of the batteries costs about $25 a year. The cost of tires, one set per year, is about $80. Paint and varnish about $20. These are the principal items of maintenance.

Mr. Guthrie.—How many miles can you make per gallon of gasoline?

Dr. Martin.—I am not familiar enough with the actual manipulation of the gasoline machine to give you exact data. I can tell you only what claims are made in this country. Gasoline carriages usually carry from three to five gallons, which quantity, we are told, will carry the machine about 100 miles. I do not believe this, but I believe about 30 miles might be made on the average American road.

(Dr. Martin here cited the trans-continental experience of Mr. and Mrs. Davis, stating that one of the greatest difficulties they met with was the difficulty of keeping supplied with gasoline.)

The steam carriage has difficulties similar to those of the gasoline, and I consider this type of motor vehicle the most dangerous in the hands of any one except machinists and experts, for the reason, mainly, that in this type of vehicle we have a flame and burner within a few inches of the gasoline tank. They also readily take fire, or become enveloped in flame from a leaky gasoline tank or its connections. In cold weather the water gauges and pipe connections freeze; and most serious of all is the ease with which a boiler is "burned out," necessitating an expenditure of from $200 to $300.

This Columbia automobile rents for $250 per month with a driver, or $200 without the driver. Others rent for $150 to $200. This includes the repairs to the machine. We take entire charge of the repairs.

Mr. Guthrie.—I move that a vote of thanks be extended to Dr. Martin for his very able and interesting address on automobiles.

Seconded by Major Symons.

Carried unanimously. Applause.

A NEW RACK AND OTHER IMPROVEMENTS TO THE FEEDER FOR THE MIDDLESEX COMPANY, LOWELL, MASS.

By Arthur T. Safford, Member Boston Society of Civil Engineers.

[Read before the Society, April 11, 1900.*]

The Middlesex Company, for the purpose of obtaining 525 net horse power for its mills at Lowell, Mass., draws from the Lower Pawtucket Canal a little less than 300 cubic feet of water per second through an old wooden feeder 210 feet long, which delivers the water into two wrought iron feeders 18 feet long. These wrought iron feeders supply two Swain wheels, side by side, 66 and 72 inches in diameter respectively, which drive, through crown and bevel gears, onto the main shaft of the mill. A steam engine of 250 horse power is belted to this shaft, and was formerly used to augment the power; but, since the improvements of this past year have been made, it is possible to run the mill entirely by water.

Fig. 1 shows the conditions before making the improvements, the location of these wheels in the mill and the feeder and its relations to the canal. The general arrangement of everything, Fig. 2, remains the same now, excepting those changes described in this paper.

Previous to the work of this last year the water was drawn from the Lower Pawtucket Canal into the feeder through an old vertical wooden rack or screen 39 feet long and 8½ feet high, the top of the rack being above running mark in the canal; the slats of the rack were of wood, being of ⅞-inch stuff with spaces 1½ inches wide between them. A rack of this character is put in to keep leaves, sticks and other *débris* from getting into the wheels. The clear area through which water could go at the high running mark of the canal, when there were no local obstructions, was 200 square feet, or 60 per cent. of the superficial area of the rack; but one-quarter of the area of the rack, downstream from the head of the feeder, did not supply its proportional part of the water on account of the proximity of the wall behind the rack. The top of the rack was at high-water mark, and if the canal was drawn down, as it often is, a foot or more, the rack area was diminished about 12 per cent. At times when ice and snow were running in the canal the clear area of the rack was further considerably reduced, on account of the ice and snow being drawn towards the rack by the current. It required constant attention during the winter season, and kept

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several men busy for a few hours each cold or snowy morning keeping the ice and snow from filling up the rack and shutting down the mill.

The velocity of the water through the old rack, with the normal quantity (300 cubic feet per second) running and the canal up to high-water mark, would average 1.5 feet per second if the rack had been so situated that each part of it supplied a proportional part of the water. This would have been ample for the present amount of water used. In actual practice not more than three-quarters of

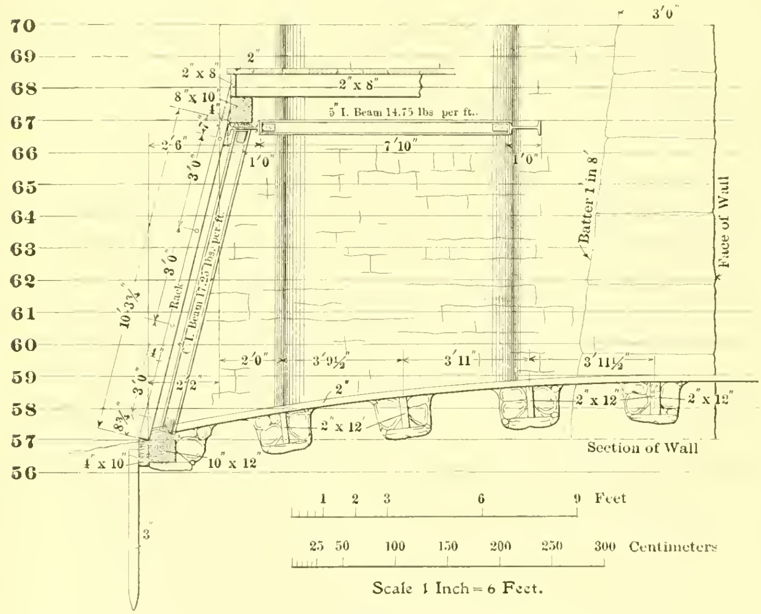


Fig. 3.
(For Figs. 1 and 2, see inset.)

the rack was in service, so that the average velocity was more than 2 feet per second.

After passing through the rack the water ran, for about 40 feet, through a section of the old feeder 27.5 feet wide and 6 feet high, containing five lines of posts, more or less in line, to support the wooden roof and the two or three feet of dirt above it. This portion of the feeder formed the head of a much older one which supplied the breast wheels of a half-century ago. Turning a right angle, the water ran for 150 feet through a channel of the same general form as the one of 40 feet already mentioned. Here the section was 20 feet wide and 6 feet high, with three lines of posts

to support the roof and the 4 to 5 feet of dirt on it; another right angle and distance of 20 feet brought the water through a section 32 feet wide and 6 feet high to a small open forebay, from which the water was drawn through a second set of racks, iron in this case, into the short wrought iron feeders which led directly to the wheels. The water, therefore, in getting from the canal to the wheels had, with various conditions of velocity and rest, to pass through two racks, turn two right angles and force its way by the lines of posts, which at the corners were oblique to the path of the water.

In addition to these obstructions, the water was constantly under a pressure of from one to two feet in going from one rack to another, so that the cross timbers supporting the roof formed a continuous line of obstructions to the flow.

The loss of head in getting from the canal to the wheels, due to this tortuous course, under the very best conditions obtainable, when the canal was free from leaves, ice and snow, was as follows:

	Loss of Head in Feet.	Area of Cross-section of Feeder in Square Feet. Approximate.	Average Velocity of Water, with 300 Cubic Feet per Second Passing.
From the canal through the first rack....	0.09	150	2.00
From behind the first rack down to the beginning of the second right angle......	0.76	134.5 115.2	2.23 2.60
From beginning of second right angle through second rack....................	0.14	203.7	1.47
From in front of second rack to point just above the wheels or penstock gauge, so called	0.32	120.5	2.49
Total loss from canal to penstock gauges	1.31		

These average velocities are obtained by dividing the quantity (300 cubic feet per second) by the area at the point observed. They are somewhat misleading, because if the velocities had not been considerably higher at some parts of each section the total loss of head would not have amounted to 1.31 feet. The head required to generate the highest velocity in the table (2.6 feet per second) is but 0.105 feet, and the friction heads would be low, with these velocities, if there were no obstructions. I have given them simply to show the effect of obstructions in consuming head. It is evident that the continued changes in velocity, the abrupt turns and constant obstructions are of more importance than the mere velocity of the water. By remedying these unfavorable conditions the losses of head were reduced to almost nothing, and this feeder was made to serve its purpose well without being enlarged, except by raising the roof.

In addition to a need of more power in the mill and the saving which would result from stopping the steam engine, there were other reasons for putting in a new rack at this time. The water had undermined the sill of the old rack at one end, and there were several bad breaks in it which had been patched, thereby increasing the obstructions to the flow of the water. The current towards the rack in winter was sufficient to draw the floating ice and snow and plaster the upper part of the rack, still further diminishing the area through which the water went and making it extremely difficult to keep the rack clean. The $1\frac{1}{2}$-inch spaces between the slats were so large that small blocks of wood, sticks, etc., went through with the water, making it necessary to have an iron rack near the wheels, which further impeded the flow of water. The position of the old rack, the top being above water, allowed scum and grease floating in the canal to be drawn into the feeder, making it necessary to further screen the water before it could be used for washing cloth. The rack, being vertical, was very difficult to rake unless the canal was drawn off.

The demands on a good rack, which were certainly not fulfilled by this old wooden one, require an area large enough to let the water through with a uniformly low velocity; spaces between the slats large enough to allow the water to go through readily, but small enough to keep out anything liable to injure the wheels; a frame and slats strong enough to resist the total pressure of the water when the rack is plastered with ice for the full depth and the water drawn out behind it, which might happen when anchor ice is running; the top of the rack to be so far below the surface of the water that the area cannot be reduced by the ordinary accumulation of ice and snow; and a surface easy to keep clean. The last requirement is an important one, as the area of a rack can be reduced to almost nothing during certain seasons of the year by leaves and *débris* if it cannot be cleaned except by getting down into the bottom when the canal is drawn off.

In order to meet these requirements it was found best to replace the wooden rack with an iron one, and the writer was asked to make, to the Holyoke Machine Company, who built the rack, whatever suggestions were necessary to make it suitable for its purpose, and to design and build the foundations necessary to set the rack in place. The improvement of the feeder had been suggested previously to the Middlesex Company, and it was decided by the treasurer of this company to allow the engineer, in connection with the other work, to do whatever seemed necessary and wise to improve the feeder, in order that the water might be

brought to the wheels with the least possible loss of head consistent with economy. The use of a hoisting engine and derrick, which were necessary to build the piers for the rack, made it possible to do the work about the penstocks more economically at this time. The only requirement on the part of the company was that nothing should be done to interfere with the running of the mills during the week, from Monday morning to Saturday noon. This required that the work be done from Saturday night to Monday morning, when the canals are drawn off, and everything be left secure when the water was let on. The inside rack, already mentioned, was left in until the work was done, to protect the wheels from floating bits of wood. Work was begun on the last Sunday but one of August, 1899, and finished before cold weather came on.

The main frame of the new rack, Figs. 2 and 3, is composed of two 12-inch steel I beams, weighing 31.5 pounds per foot, placed 8 feet 10 inches apart on centers, set with the webs flat and the ends resting on pockets built in the masonry walls forming the head of the feeder. The one against which the rack irons are laid is 51 feet 4 inches long. Both of these I beams are set with the top of each flange at grade 67 on the scale of heights used, or about one foot below the ordinary running mark of the canal.

The span of 50 feet of the longer 12-inch beam is divided into three parts, of 16 feet 8 inches each, by two 6-inch steel I beams weighing 17.25 pounds per foot, the upper ends of which are fastened to the web of the 12-inch beam by angle irons; the lower ends, by means of angle irons, are lag-screwed to the main sill supporting the entire rack, and not bolted, as the section (Fig. 3) shows it. The other 12-inch beam, also of steel, weighing 31.5 pounds per foot, is 29 feet 6 inches long, the span being two feet less than this, or the full width of the feeder (Fig. 2). The span of 27 feet 6 inches is divided into two, of 13 feet 8 inches each, by a Georgia pine pier, sharpened back and front, so as to offer as little obstruction to the water as possible. Two 5-inch I beams, Fig. 3, weighing 14.75 pounds per foot, are placed between the two 12-inch beams at a distance of 5 feet 5 inches from each side of the feeder and in line with the two 6-inch beams mentioned before. They are level with the 12-inch beams, or a foot below the running mark, and serve to stiffen the rack.

The rack proper is 50 feet long and 10 feet high measured vertically, and has a clear area for the water of about 389 square feet. It is composed of panels of 4 x $\frac{1}{4}$-inch flat wrought iron bars 10 feet $3\frac{3}{4}$ inches long. They are held together by four $\frac{3}{4}$-inch bolts about 2 feet 6 inches long, making a panel of that width, with

$\frac{3}{8}$-inch washers to space the bars. These bolts are not set in the middle of the 4-inch bars, but back $2\frac{1}{2}$ inches from the front edge for convenience in raking the rack. These bolts divide the rack into three sections of 3 feet each, the top bolts being 7 inches from the end of the rack and the bottom ones $8\frac{3}{4}$ inches from the sill. These panels rest on the sill of the rack, which will be described later, and lean against the outer flange of the 12-inch I beam, each panel being hooked to the I beam to prevent the rack from being pushed out into the canal. The rack has a batter of 2 feet 6 inches in the 10 feet $3\frac{3}{4}$ inches, which slope makes it possible to rake the panels from the bottom up. The washers between the rack irons, which form the only obstruction to raking, are set back $2\frac{1}{2}$ inches from the front, as mentioned before, and, being rounded, they allow the teeth of the rake to pass between the rack irons without catching. Each panel of the rack was painted with black coal tar paint before being set in place.

The walls which support the ends of the two 12-inch beams carrying the rack form the head of the feeder. They are built upon the ends of a wooden floor for a distance of 16 feet from the sill supporting the racks back into the feeder, and form an opening which is ample to carry the water from behind the racks into the feeder proper without requiring any new loss of head in generating an increased velocity. The form of the opening behind the racks was such that each foot of rack, even to the extreme ends, would furnish its proportional amount of water.

The floor mentioned, Fig. 3, was laid lengthwise with the line of the feeder, over sills made up of 2-inch spruce plank 12 inches wide, to the bottom of which were spiked three-cornered cleats of spruce. These sills were laid in trenches dug just wide enough to get them in and the cleats covered with stone, and in some cases, where the material was wet, with concrete. These sills were laid at such a grade as would just allow the 2-inch spruce planking, planed on the upper side, to be bent, from the sill on which the rack rested, over the 12-inch sills to the grade required at the end of the 16-foot section. The sill to which the planking was spiked was composed of a 10 x 12-inch Georgia pine timber, the top of which was beveled to receive the two 6-inch beams forming the framework of the rack. To the back of this timber was nailed a cleat which was covered with concrete and stones, the trench being dug wide enough to allow stones a foot wide to be laid upon the cleat.

Spiked to this 10 x 12-inch timber, and in front of it, was a 4 x 10-inch Georgia pine timber with its top 4 inches below the top of the main sill, fashioned to receive the rack irons. The toe piling,

shown on the section, was composed of 3-inch tongued and grooved spruce plank, driven as far as possible by hand to depths from 2 to 4 feet below the top grade, as shown. This sheet piling was cut off a few inches below the top of the sill to provide for a possible flooring of the canal outside of the rack.

With the draft through the rack so light, on account of the increased area of the new rack, there may be some depositing of material on the bottom at the end of the floor, on account of its being nearly two feet lower than the general level of the bottom; but if provision is made for using nearly double the present quantity of water no such deposit will occur, and the area at this low level offsets that lost by burying the top of the rack under water.

FIG. 4.

The new sill, besides being two feet lower, was located some few feet in front of the old one, and the two piers supporting the ends of the I beams were entirely outside the old feeder. These conditions allowed the new sills and a part of the flooring and walls to be put in without disturbing the old feeder. Fig. 4 shows the new sill in front of the old feeder and the new floor being laid.

The front of the pier is laid to the same batter as the rack irons when in place. The two piers at the head of the feeder, and a part of the feeder wall, were built, before the old feeder was taken out of the way, with a derrick, which was on the old feeder and placed so as to reach either pier at will. This made it possible to fill in behind both piers and prevent any washing of the bank here during the week when the mills were running.

While the two walls at the head of the feeder, and the sills and floor were being built about 2500 yards of material had been taken off the top of the feeder around to the mill wall, the last foot in depth being removed after the canals had been drawn off the Saturday night before Labor Day. During the next two days the roof timbers and planking forming the top of the old feeder were jacked up and lifted about three feet to a point above the high-water mark in the canal, and the blocking securely fastened so that it would not float away during the week. The walls were built up to meet the ends of the timbers supporting the roof, and a new line of 8 x 4-inch spruce posts was put in on the middle line of the feeder and sheathed on both sides with 1-inch boards, smooth on the water

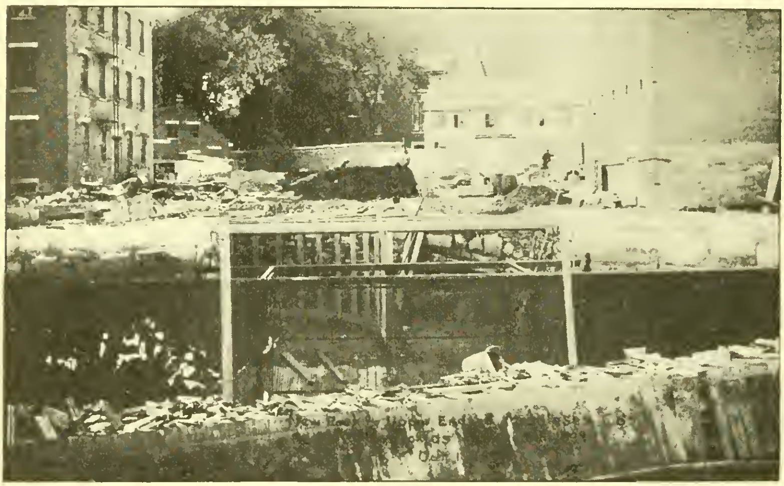


Fig. 5.

side, making two continuous partitions from a point 12 feet back of the new rack to the end of the section 150 feet long. The walls were rebuilt, and the corners rounded off with a rubble masonry wall pointed up as smoothly as possible.

Fig. 5 shows well the rack in place and the new central line of posts supporting the roof.

As the old yellow pine cross timbers supporting the roof were sound, and as they can be renewed readily, they were reset; the planking was patched up where necessary, and about one foot of earth was put back over the roof and graded off. There is left above the water an air space of about 6 inches and a foot of dirt, which during the past winter has been sufficient to keep the water in the feeder from freezing.

At the lower end of the feeder, at the second right angle, the masonry wall was built around to the mill only on one side; on the other side the curve was made by a wooden sheathed wall. The situation of the wheels was such that it became necessary to put in what might be called a curved arrow-head of wooden sheathing in order to bring the water to the wheels by an easy turn without changing the velocity. This simply required taking out all posts and putting in new ones on the line of the proposed sheathing and bending the 1-inch boards to the posts as laid out on the curve. The posts, to which the sheathing was nailed, carry the floor timbers as rearranged. The sheathing was not carried further down than a point within 3 feet of the floor, in order that there might be an opening from one feeder to the other in case one wheel only was running and it was necessary to use both feeders to supply it.

During the rebuilding of this feeder it was found that an old leak near the outside lower corner of the feeder had increased materially, due to the greater head on the leak caused by the improvements. A row of 2-inch tongued-and-grooved sheet piling 12 feet long was placed in the middle of a trench 3 feet wide, at a distance of 6.5 feet from the line of the old feeder down to a point below the bottom of the feeder, the top being well above high-water mark; and the trench was filled in on both sides of the piling with the best puddling material available on the work. This stopped the leak entirely, and it affords a complete protection to the basements of the mills, which are about 8 feet below the height of the water in the bank back of this sheet piling.

The bottom of the feeder was not changed, excepting the floor put in at the head of the feeder and already described. The bottom is composed of loose gravel and stone, with the ledge appearing in several places. This was simply cleaned up and left as smooth as scraping could make it. The gain due to diminishing the friction by the removal of the posts and the rounding of the corners was so great that it did not seem necessary to floor the feeder at present. It may be wise at some future time, when the draft through the feeder becomes greater, to lay a floor the entire length.

The difficulties attending work of this character are principally due to the short time possible for the completion of each section of the work.

The work would probably not have been undertaken by the Middlesex Company if there had been any stopping of their work during the regular week of fifty-eight hours, from Monday morning to Saturday noon. From the time the water was drawn off on Saturday night until Monday morning at six o'clock, the work was

so carried out that everything was in readiness to leave when the water was turned on. It required the attention of an engineer on the work continuously, to see that the work was carried on as expeditiously as possible.

Outside of these limitations of time, there were no unusual difficulties except the necessity of handling large quantities of water by pumps until the canal was entirely drained off. The material in the bottom was shoveled into dirt boxes and hoisted out by the derrick, deposited in piles and removed during the week. The laying of the sills and floor and other woodwork was done by carpenters furnished by the Middlesex Company; and all other work, including stone cutting, by a contractor, who furnished men and tools for a percentage of the cost of labor and materials used.

The masonry work was all granite rubble, laid in American Hoffman cement, excepting the piers at the head, which were cut from granite blocks to dimension by a stone cutter in the yard; laid as carefully as possible to line and grade, and pointed off smoothly on the inside or water side.

This work was completed during the Sundays of August, September, October and November, 1899. The first Monday of September being a mill holiday made it possible to have two days in succession, and some of the more difficult work of lifting the roof and getting in the sills was done then. Some of the material, down to the water, could be stripped off during the ordinary working days, and, by building certain sections of the masonry up above water line, the rest could be finished during the day or night. This, however, was a small part of the whole, most of the work being done Saturday night and Sunday. It was necessarily expensive work, as all labor was paid for at the rate of time and one-half for night and Sunday work, and it is not possible to get a good class of labor for work of this character. The total cost of all the work, including engineering and contractors' percentage, was about $5000.

The following table shows the height of water at different points, from the Lower Pawtucket Canal, through the feeder, to just above the wheels, before and since the improvements were made:

	July 22, 1898.	January 23, 1900.
Lower Pawtucket Canal	68.12	68.10
Just inside rack at head of feeder	68.03	68.02
Beginning of second right angle	67.27	67.98
Above location of old iron rack	67.13	68.03
Just above wheels (penstock gauges)	66.805	67.95
Quantity passing, cubic feet per second	301.9	280.3

With the water in the canal at about the same height as before the improvements were made, the total effective head on the wheels (now 20.16 feet) is 1.16 feet (or 6 per cent.) greater than it was before, the water being but 0.15 foot lower at the wheels than in the canal after passing through the racks and feeder, instead of 1.31 feet, as it was formerly. This increased head makes it possible to draw about 3 per cent. more water through the same wheels than before, which amount of water is available as power with the total fall as improved. The gain is about 50 horse power; worth to the mill probably $1500 a year, in addition to the saving, in labor, of clearing the racks in winter. The quantity running on the 23d of January, 1900, was not quite as large as that on July 22, 1898.

Fig. 6.

Hence the foregoing table, which shows the losses of head on those dates, is somewhat in favor of the conditions as improved.

A comparison, under ordinary working conditions in the mill, on two days when the quantity drawn through the feeder was the same shows the following losses of head from the Lower Pawtucket Canal to the penstock gauges:

	December [illegible], 1898.	April 5, 1900.
Lower Pawtucket Canal	68.10	68.10
Just above wheels (penstock gauges)	67.02	67.93
Loss of head from canal to just above wheels, in feet	1.08	0.17
Saving in loss of head	....	0.91
Quantity drawn through feeder in cubic feet per second	282.8	282.1

There was no loss through the feeder from "just inside rack at head of feeder" to gauge "above location of old iron rack" on January 23, 1900, as against 0.9 foot on July 22, 1898. The latter loss, with 280.3 cubic feet per second, or the same quantity running as on the first date, would have been about 0.77 foot. This difference of 0.77 foot shows the loss through the feeder due to the posts and the sharp turns.

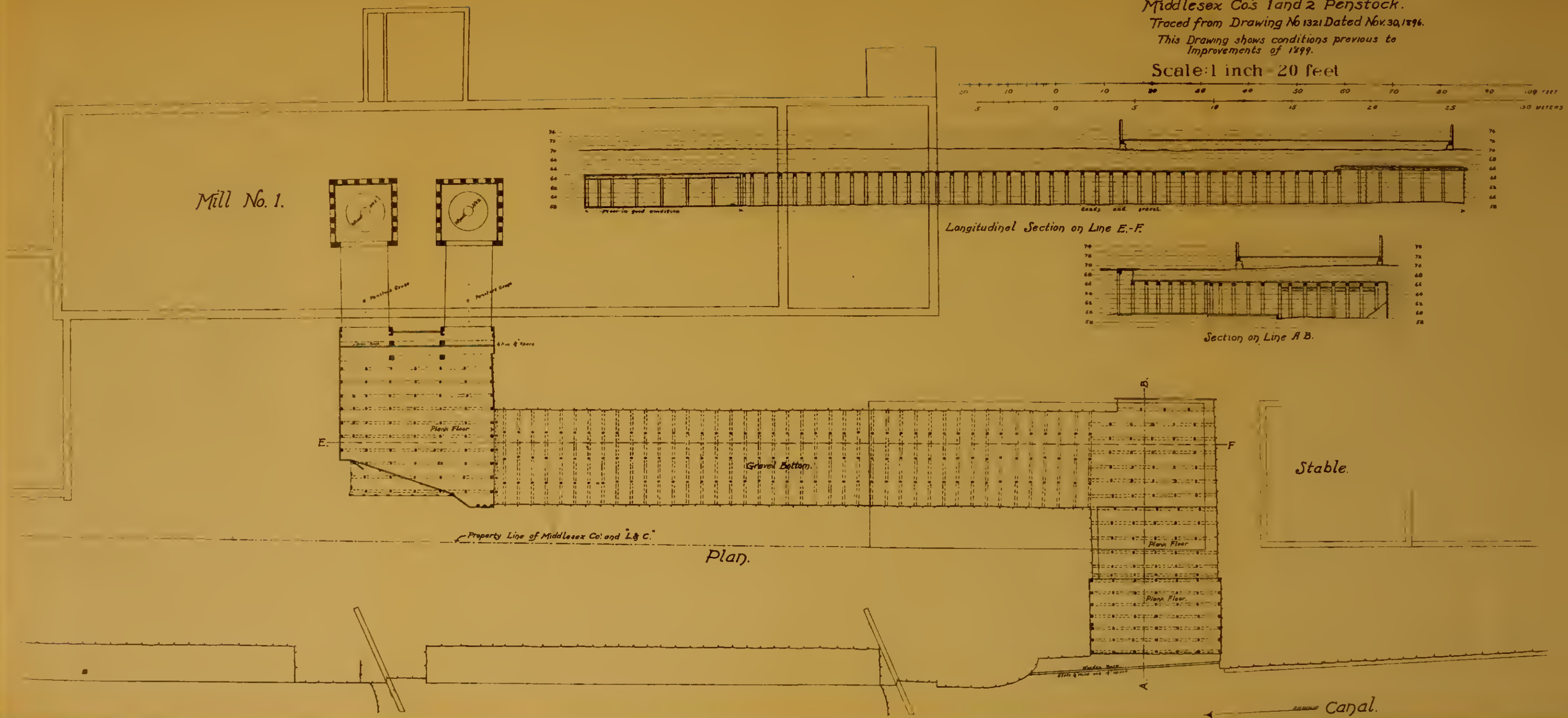
In addition to the actual gain in effective head, the freedom from trouble by ice and snow is a very important help. With the top of the new rack under water there is little chance of its being plastered up with ice and snow, which formerly necessitated the shutting down of the mills until the racks could be cleaned, and required a number of men for several hours during the winter season. Only two shut-downs were necessary during the past winter. This is a very noticeable improvement, because, although it was a mild winter, the amount of anchor ice was unusually large.

Fig. 6 shows the pile of *débris* which has been taken from the rack up onto the platform above it.

It is not intended to create the impression that this work was of any considerable magnitude. It is simply an example of the many interesting problems which come up in a place like Lowell, Mass., where a hydraulic engineer is asked to improve the water power in the short time available out of mill hours; and where the work is appreciated not solely for actually increasing the water power of the mill, but for simplifying the conditions under which the water power can be controlled.

In the design and execution of this work I have had the assistance of Mr. George W. Mansur, of Lowell, Mass., and I am deeply indebted to him for his interest and energy in obtaining the results required.

FIG. 1.
Scale Drawing of
Middlesex Co's 1 and 2 Penstock.
Traced from Drawing No 1321 Dated Nov. 30, 1896.
This Drawing shows conditions previous to Improvements of 1899.
Scale: 1 inch = 20 feet



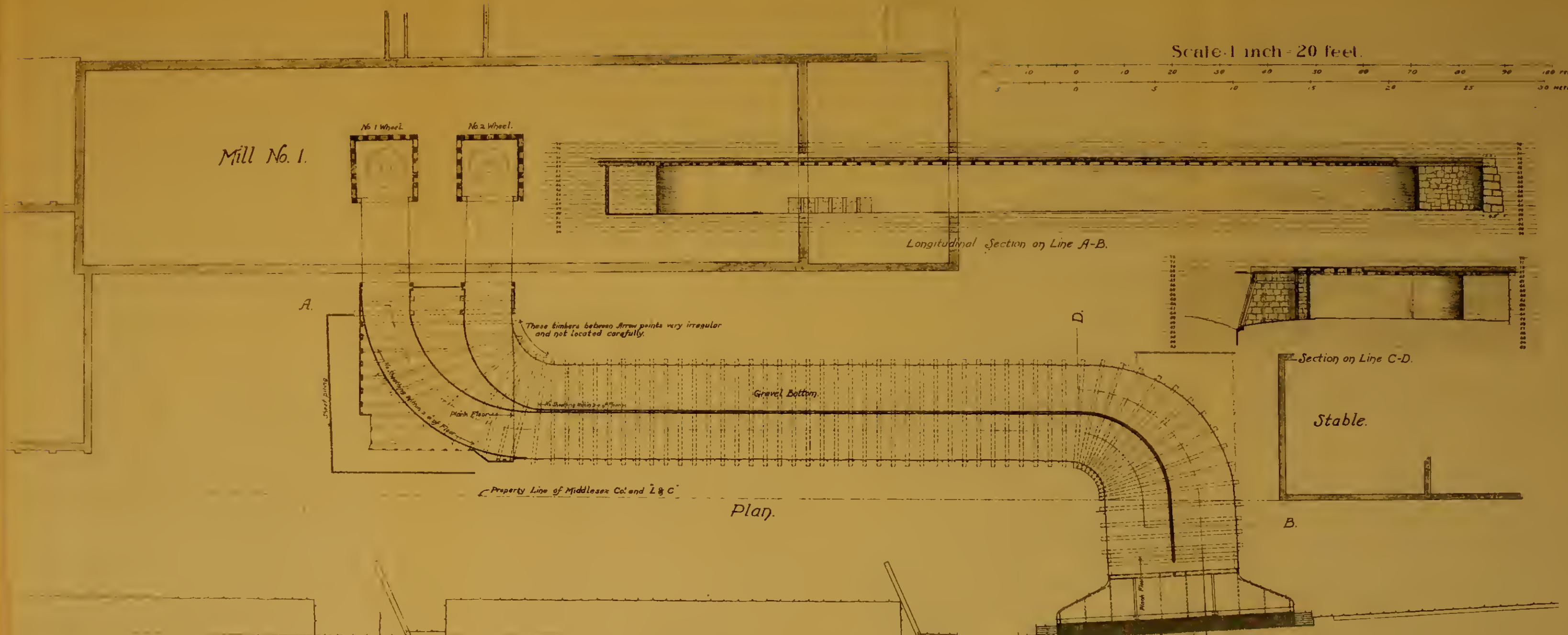


FIG. 2.
Scale Drawing of
Middlesex Co's. New Racks and Improved Penstock
for No. 1 and 2 Wheels.
Oct. 27, 1899

THE INIDIKIL SYSTEM.

A Decimal System of Weights and Measures for the English-Speaking People.

By A. Lincoln Hyde, Ph.B., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, June 12, 1900.*]

"Progress is the law of life," said Robert Browning, and I believe we all agree that we live to progress. Man was given senses to appreciate nature, and a brain to adapt the products and forces of nature to his convenience and comfort. The inventive mind is ever at work in an endeavor to discover a new force, or a new method of applying a known force. The tendency is ever toward simplicity, ever toward economy. The effort of the mechanical engineer is to reduce the number of working parts of a machine, to reduce the friction, to obtain the best possible results with the least expenditure of energy.

In the June number of the *Century*, Mr. Nikola Tesla has a paper entitled "The Problem of Increasing Human Energy." The problem with which we have to deal to-night is the problem of saving mental energy. A system of coinage is a convenience for the measure of values, and a system of weights and measures is a convenience for the measure of materials. No fault is found with the system of coinage in use in the United States, but the prevailing system of weights and measures is far from being the most convenient that could be used. A new system is suggested. It is founded on the common unit of the present system. The number of working parts has been reduced to reasonable limits and the parts themselves have been made as simple as possible.

As far as its application to abstract numbers is concerned, the Arabic or decimal system of notation has been accepted as best by all nations. To the French people belongs the credit of first having applied it to a standard of weights and measures. Although the suggestion of such action was made in the time of Philippe le Bel, who reigned from 1285 to 1314, the scheme did not take definite form until 1790, when proposals were made by the French Government to the British for a meeting of an equal number of members from the Academy of Sciences and the Royal Society of London, with a view to making a new system of measures. The proposals were not favorably received by the British, and the French, impatient to effect the much-needed reform, appointed the commission which evolved the metric system. This system received legal sanc-

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tion by the French Government November 2, 1801, and has been the only system in general use in France since 1840.

It might be said that if the overtures made by the French in 1790 had met the favorable consideration of the British, the metric system would have been the universal and only system in use to-day. Little is gained by dwelling on what might have been. It is far better for us to adapt ourselves to the conditions as we find them, and to date our efforts in the line of progress from the present.

The metric system was the result of careful deliberation and logical reasoning. Its practical use has developed two points. The number of terms for units adopted was too large, and the terms themselves are too cumbersome for general practice. About one-half the number of terms adopted are in common use, and it has been found necessary to abbreviate these and to designate them by their initial letters.

The metric system was at first met with the opposition of prejudice and lack of appreciation, and was nearly a half-century in establishing itself in the country which created it. Its value was recognized at once, however, by scientists, and its use was legalized by the several greater nations. Germany very gracefully adopted it immediately after the close of the Franco-Prussian War, and Russia accepted it about a year ago. It is the standard of Italy, Spain and Mexico, as well as that of almost all of the smaller countries. It is stated as true that the metric system is now used by the majority of the people of the globe, but, notwithstand this fact, if it, indeed, be a fact, the two great manufacturing nations of the world, Great Britain and the United States, have not yet seen fit to adopt it.

The reason for suggesting a decimal system of weights and measures for the English-speaking nations is due to the fact that the numerous and strenuous efforts to have the use of the metric system made compulsory in Great Britain and the United States have ignominiously failed. The development of industries in these countries has been so great and along such lines that they are growing away from rather than towards the use of the metric system.

The most just opposition to the introduction of the metric system into the United States to-day is met in the machine shop. The amount of capital invested in machinery and in the manufacture of machinery is so enormous as practically to prohibit the adoption of this admirable system.

It does not necessarily follow that because we cannot accept the metric system, we must bend forever beneath the burden of our present brain-fagging and error-producing systems.

In these days of advancement it is an unnatural retardation of progress to cling tenaciously to systems of linear and surface measure with arbitrary modes of division; to cling to three systems of measure of capacity when one will suffice; to cling to three systems of weight. An improvement on the present practice must be made sooner or later.

The surveyor, for his convenience, has divided the foot into tenths, hundredths and thousandths, but for the machine shop and the rolling mill the foot is no better than the meter as a basis of a decimal system.

The inch, however, is a unit common to all, and is the logical basis for a decimal system of weights and measures. The fractions of an inch in general use are exact decimals of an inch. The micrometer scales in the machine shop and in the physical laboratory read to tenths, hundredths and thousandths of an inch. Nominally, the yard is the standard of English measure, and the foot and the inch are subdivisions of the yard. In reality the inch is the common unit of English measure, and should be adopted as the standard. The inch is already divided decimally. Let us multiply it by ten for a new unit, and let us multiply this new unit by ten for another, and so on, until a sufficient number of units has been obtained to meet our needs. The time is ripe for the banishment of both the foot and the yard.

Let us build a decimal system of weights and measures on the inch as a basis.

We have stated that the only just opposition to the metric system has come from the machine shop. In building a decimal system on the inch we cannot be met with just opposition from the machine shop; we cannot be met with just opposition from the surveyor; we cannot be met with just opposition from any source.

In selecting unit terms for the proposed system let us profit by the experience of the metric system. Four terms each for units of length, area, capacity and weight will be sufficient for all ordinary purposes. Let us make our terms so simple that they will require no abbreviation. Let us agree that the plurals of the terms shall be the same as the singulars.

In introducing new words into the English language it is customary to borrow from some foreign language—living or dead. Let us be bold enough to coin the terms necessary for our use from the raw material of the alphabet. Two letters, one vowel and one consonant, are sufficient to form a pronounceable word, and one that will require no abbreviation. Let us so form our terms.

Starting with linear measure, we know that the word inch is usually abbreviated to *in* by those who have occasion frequently to use the word. Let us accept this as satisfactory for one term, and for the other three terms let us combine the same vowel *i* with three such consonants as will prevent any one term being mistaken for any other term, either in writing or speaking. The three consonants *d, k* and *l* will meet these requirements, and our terms will be *in, id, ik* and *il.*

For the units of surface measure let us simply abbreviate the word square to *sq,* and add respectively the terms selected for linear measure. Our terms for units of measure of area will be *sqin, sqid, sqik* and *sqil.*

In selecting terms for designating units of capacity let us agree at the outset that one set of terms for units of cubical contents of all kinds will suffice. Let us abbreviate the word cubic to *cub,* and add respectively the terms for linear measure as before. Our terms for units of measure of capacity will be *cubin, cubid, cubik* and *cubil.*

In a similar manner let us select terms for units of weight. We can do no better than follow the example of the metric system in selecting the basis for our system of weights. Let us use the weight of one cubic inch or *cubin* of distilled water at its greatest density, 4 degrees Centigrade, the barometer standing at 30 inches or 3 *id.* Let us designate the units, tens, hundreds and thousands of this weight by simple terms coined as before from two letters. Let us use the first letter of the alphabet for the vowel in connection with the same consonants used in our terms for linear measure, and in the same order. Our terms for units of weights will be *an, ad, ak* and *al.*

Our tables of value are simple, and are as follows:

Measure of Length.

In	1 in	1 inch
Id	10 in	10 inches
Ik	100 in	100 inches
Il	1,000 in	1,000 inches

Measure of Surface.

Sqin	1 sqin	1 square inch
Sqid	100 sqin	100 square inches
Sqik	10,000 sqin	10,000 square inches
Sqil	1,000,000 sqin	1,000,000 square inches

MEASURE OF CAPACITY.

Cubin	1 cubin	1 cubic inch
Cubid	1,000 cubin	1,000 cubic inches
Cubik	1,000,000 cubin	1,000,000 cubic inches
Cubil	1,000,000,000 cubin	1,000,000,000 cubic inches

WEIGHT.

An	1 an	weight of	1 cubic inch	of water
Ad	10 an	weight of	10 cubic inches	of water
Ak	100 an	weight of	100 cubic inches	of water
Al	1,000 an	weight of	1,000 cubic inches	of water

In order to distinguish the proposed decimal system of weights and measures from the prevailing systems, let us give it a name. If we combine the terms selected for units of linear measure in regular order we shall have the word *in-id-ik-il*. This is certainly euphonious and easily remembered. Further, it is a master key to the entire system, the substitution of the vowel *a* for the vowel *i* giving the key to the system of weights.

Having decided upon our units, it is a simple matter to make a table of equivalents for use during the transition period. To reduce from the common or English system to the *inidikil system* it is only necessary to reduce to inches, square inches or cubic inches, as the case may require, and to put the decimal point in the proper place. The reduction of weights from one system to the other is also very easily effected.

Tables showing the precise equivalents of the common units of the three systems, English, metric and *inidikil*, each in terms of the other two are given on pages 43, 44 and 45, and a table of precise equivalents of the common units of the *inidikil* and metric systems, each in terms of the other, is given on page 46.

In the table of precise equivalents now in general use by those who have occasion to translate from the English to the metric system and *vice versa*,—comprising the tables on pages 43 to 45 with the middle column omitted,—there are thirty-nine factors, while in the table on page 46, which would be used if the proposed *inidikil system* were adopted, *there are but six*.

The advantages claimed for the *inidikil system* are the advantages which obtain in the use of any decimal system; the ease with which the change from the English system can be made; the close relationship to the metric system; the simplicity of the system itself, and the economy resulting from its use.

The advantages of a decimal system are too well known to require demonstration. A mental comparison of the monetary systems of Great Britain and the United States is sufficient to convince the average mind.

The ease with which the change can be made must readily be comprehended. For the present it simply means the adoption of one new unit-term equal to ten inches. Time can be taken to perfect the suggested system and to make provision for the change. The inch is already establishing itself as the only unit of linear measure in the machine shop. In the rolling mill the widths and thicknesses of all plates, the sizes and thicknesses of all shapes, are given in inches. In the boiler shop all dimensions of plates are given in inches. All dimensions of plate glass are given in inches. The dimensions of pictures in our art galleries are given in inches. The widths of cloth, wall paper, carpeting, draperies, etc., are given in inches. Then why not all dimensions of all materials in inches or in decimal multiplications or decimal divisions of the inch?

The plasterer measures his surfaces with a foot rule, computes his areas in square feet and faithfully divides by nine to reduce to square yards. The stone mason also measures his work with a foot rule, computes his contents in cubic feet and divides by twenty-seven to reduce to cubic yards. And this, day in and day out, year in and year out, on every job that is figured. Surely, some men must love work for work's sake, since nothing is accomplished by these long-continued senseless operations. But it is custom! Energy always has been wasted in this way; it has come to be an established custom to waste energy in this way, therefore we must always waste energy in this way!

We have made some progress. When we think of the list of terms, including the barleycorn, inch, digit, palm, hand, link, span, foot, cubit, yard, ell, fathom, rod or pole, chain, furlong, cable's length, statute mile, nautical mile, knot, league, square inch, square foot, square yard, square of one hundred square feet, square rod or perch, rood, acre, quarter-section, square mile or section, township, cubic inch, cubic foot, cubic yard, perch of sixteen and one-half cubic feet, perch of twenty-two cubic feet, perch of twenty-four and three-quarters cubic feet, ton of one hundred cubic feet, cord, fluid minim, drachm and ounce, liquid gill, pint, quart and gallon, dry quart, peck and bushel, grain, scruple, pennyweight, drachm, ounce (Troy), ounce (avoirdupois), pound (Troy), pound (avoirdupois), stone, quarter, quintal, hundredweight, net ton and gross or long ton, when we think of the sea of radices: 2, 3, 4, 5.5,

6, 7.92, 8, 9, 12, 14, 16, 16.5, 20, 22, 24, 24.75, 27, 28, 36, 40, 66, 80, 100, 112, 120, 128, 144, 160, 231, 437.5, 480, 1728, 2150.42, etc.—when we think of all this, we cannot help feeling that we have made some progress. But we have not made sufficient progress. Even now our system of weights and measures is "an unweeded garden that grows to seed; things rank and gross in nature possess it merely." A system of twelve simple terms with a single radix, ten, is sufficient for the convenient handling of the general business of the English-speaking nations.

Simplicity is claimed for the proposed *inidikil system* and a comparison in parallel of the three systems, English, metric and *inidikil*, will bear out this claim.

English.	*Metric.*	*Inidikil.*
inch	millimetre	in
foot	centimetre	id
yard	metre	il
mile	kilometre	sqin
square inch	centare	sqid
square foot	are	sqil
square yard	hectare	cubin
square	cubic centimetre	cubid
acre	litre	cubik
cubic inch	cubic metre	an
cubic foot	gram	ad
perch	tonne	al
cubic yard	kilo	
cord		
minim		
drachm		
ounce		
gill		
pint		
quart		
gallon		
quart		
peck		
bushel		
grain		
scruple		
pennyweight		
drachm		
ounce (Troy)		
ounce (Av'd)		
pound (Troy)		
pound (Av'd)		
hundredweight		
ton (net)		
ton (gross or long)		

Economy is also claimed. To the person who does not use weights and measures the system signifies little or nothing, but to the man whose daily work is made up of arithmetical operations involving terms representing weights and measures it signifies much. Aside from the bookkeeper, who uses figures to represent dollars and cents, and who, in this respect, is well taken care of by a deci-

mal system, the structural draftsman, perhaps, uses the most figures in his work. Next in order come the architect, civil engineer and mechanical engineer.

To prove our claim of economy, let us again try the "deadly parallel." I give below one line of dimensions taken from the working drawing for an ordinary built-up column composed of two ten-inch channels laced, and in parallel the dimensions as they would appear if the *inidikil system* were in vogue.

English System.		*Inidikil System.*	
	0′ — 2″		0′.2
	0′ — 2½″		0′.25
	0′ — 3½″		0′.35
	0′ — 3½″		0′.35
	0′ — 2½″		0′.25
6 spa. @ 3¼″	1′ — 7½″	6 spa. @ 3″.25	1′.95
	0′ — 2¾″		0′.34
28 spa. @ 5⅞″	13′ — 8½″	28 spa. @ 5″.85	16′.38
3 spa. @ 4½″	1′ — 1½″	3 spa. @ 4″.5	1′.35
	0′ — 2¼″		0′.23
	0′ — 2¼″		0′.23
3 spa. @ 4½″	1′ — 1½″	3 spa. @ 4″.5	1′.35
28 spa. @ 5⅞″	13′ — 8½″	28 spa. @ 5″.85	16′.38
3 spa. @ 4 3/16″	1′ — 0 9/16″	3 spa. @ 4″.4	1′.32
	0′ — 2 3/16″		0′.22
	0′ — 2 3/16″		0′.25
3 spa. @ 4 3/16″	1′ — 0 9/16″	3 spa. @ 4″.25	1′.275
25 spa. @ 5⅞″	12′ — 2⅞″	25 spa. @ 5″.85	14′.625
15 spa. @ 4⅛″	5′ — 1⅞″	15 spa. @ 4″.15	6′.225
	0′ — 5⅛″		0′.475
	0′ — 1⅜″		0′.15
	53′ — 5½″		64′.15

By checking the multiplications indicated and the total length of the column by adding the minor dimensions, some idea of the time that would be saved by using the *inidikil system* will be gained. Remember that this is but one line of dimensions. On one twenty-four by thirty-six-inch sheet working drawing there are from thirty to fifty times as many figures as are here given, and the number of sheets to a job varies from five to one hundred.

It is known that about one-third the total time spent on a working drawing is given to the arithmetical calculations and to the putting down of figures or dimensions. It is also known that it takes about one-third as long to check a working plan as to make a complete working plan. It is believed that fifty per cent. of the time spent in making the arithmetical calculations and putting down the dimensions, and fifty per cent. of the checker's time, or twenty-five per cent. of the whole time spent on a working drawing, could be saved by the use of the *inidikil system.* Suppose a bridge company employs ten draftsmen at an average of $1000 each per year and the company could save ten per cent. or $1000

per year, would not this amount be worth saving? I am confident that a company in such a case could save from $1000 to $2500 by using the proposed decimal system. There are several companies employing regularly from thirty to fifty and some as high as a hundred draftsmen. For a company employing fifty draftsmen the saving would be in the neighborhood of $10,000, or the interest on an investment of $250,000. Surely such an amount must be worth saving! And this is in the drafting department alone; there would also be a saving in the engineering or estimating department, and in the shop. All manufacturers would be benefited, all engineers, all architects, all users of a system of weights and measures. In addition to the great financial saving, all draftsmen and checkers would be relieved of a great mental strain.

ENGLISH SYSTEM.

Table of Precise Equivalents in Terms of Inidikil and Metric Systems.

English.	Inidikil.	Metric.
1 inch	1.0000 in	2.5400 cm.
1 foot	1.2000 id	30.4800 cm.
1 yard	3.6000 id	0.9144 m.
1 mile	63.3600 il	1.6093 km.
1 sq. inch	1.0000 sqin	6.4516 sq. cm.
1 sq. foot	1.4400 sqid	0.0929 sq. m.
1 sq. yard	12.9600 sqid	0.8361 sq. m.
1 acre	6.2726 sqil	0.4047 hectar
1 cu. inch	1.0000 cubin	16.3900 cu. cm.
1 cu. foot	1.7280 cubid	0.0283 cu. m.
1 cu. yard	46.6560 cubid	0.7645 cu. m.
1 pint (liq.)	28.8750 cubin	0.4732 litres
1 quart (liq.)	57.7500 cubin	0.9463 litres
1 quart (dry)	67.2000 cubin	1.1010 litres
1 gallon	231.0000 cubin	3.7853 litres
1 peck	537.6000 cubin	8.8090 litres
1 bushel	2.1504 cubid	35.2360 litres
1 grain	0.00396 an	0.0648 gram
1 ounce (Av'd)	1.73010 an	28.3526 grams
1 ounce (Troy)	1.90100 an	31.1038 grams
1 pound (Av'd)	2.76820 ad	0.4536 kilo
1 ton (2,000 lbs.)	55.36400 al	0.9072 tonnes
1 ton (2,240 lbs.)	62.00770 al	1.0170 tonnes

METRIC SYSTEM.

TABLE OF PRECISE EQUIVALENTS IN TERMS OF INIDIKIL AND ENGLISH SYSTEMS.

METRIC.	INIDIKIL.	ENGLISH.
1 mm.	0.0394 in	0.0394 inch
1 cm.	0.3937 in	0.3937 inch
1 m.	3.9370 id	3.2809 feet
1 km.	39.3700 il	0.6214 miles
1 sq. cm.	0.1550 sqin	0.1550 sq. in.
1 sq. m.	15.5000 sqid	1.1960 sq. yds.
1 hectar	15.5000 sqil	2.4710 acres
1 cu. cm.	0.0610 cubin	0.0610 cu. in.
1 litre	61.0234 cubin	0.9081 q'rt (dry)
1 litre	61.0234 cubin	1.0567 q'rt (liq.)
1 cu. m.	61.0234 cubid	1.3078 cu. yds.
1 gram	0.0610 an	15.4306 grains
1 kilo	6.1022 ad	2.2046 pounds
1 tonne	61.0222 al	1.1020 tons (2000 lbs.)
1 tonne	61.0222 al	0.9842 tons (2240 lbs.)

INIDIKIL SYSTEM.

Table of Precise Equivalents in Terms of English and Metric Systems.

Inidikil.	English.	Metric.
1 in	1.0000 inch	2.5400 cm.
1 id	0.8333 foot	25.4000 cm.
1 ik	8.3333 feet	2.5400 m.
1 il	83.3333 feet	25 4000 m.
1 sqin	1.0000 sq. inch	6.4516 sq. cm.
1 sqid	0.6944 sq. foot	645.1600 sq. cm.
1 sqik	7.7160 sq. yards	6.4516 sq. m.
1 sqil	771.6044 sq. yards	645.1600 sq. m.
1 cubin	1.0000 cu. inch 0.5541 fluid oz.	16 3900 cu. cm.
1 cubid	0.5787 cu. foot 4.3290 gallons 0.4650 bushels	16.3900 litres
1 cubik	21.4324 cu. yards	16.3900 cu. m.
1 an	252.6983 grains 12.6347 scruples 10.5289 pwts. 4.2116 drachms 0.5265 oz. (Troy) 0.5776 oz. (Av'd)	16.3900 grams
1 ad	5.2644 oz. (Troy) 5.7759 oz. (Av'd)	163.9000 grams
1 ak	4.3870 lbs. (Troy) 3.6099 lbs. (Av'd)	1.6390 kilos
1 al	36.0991 lbs. (Av'd)	16.3900 kilos

INIDIKIL AND METRIC SYSTEMS.

Precise Equivalents.

Inidikil.	Metric.	Metric.	Inidikil.
1 in	2.5400 cm.	1 cm.	0.3937 in
1 id	0.2540 m.	1 m.	3.9370 id
1 il	25.4000 m.	1 km.	39.3700 il
1 sqin	6.4516 sq. cm.	1 sq. cm.	0.1550 sqin
1 sqid	0.0645 sq. m.	1 sq m.	15.5000 sqid
1 cubin	16.3900 cu. cm.	1 cu. cm.	0.0610 cubin
1 cubid	16.3900 litres	1 litre	0.0610 cubid
1 cubik	16.3900 cu. m.	1 cu. m.	0.0610 cubik
1 an	16.3900 grams	1 gram	0.0610 an
1 ad	0.1639 kilo	1 kilo	6.1022 ad
1 al	16.3900 kilos	1 tonne	61.0222 al

A few illustrations will serve to show some of the values that would come into general use if the *inidikil system* were accepted. The equivalent and the value now in use are given for comparison.

DOMESTIC POSTAGE.

Matter.	Rate.	New.	Equivalent.	Old.
First Class Letters, etc.	2c.	2 an	1.16 oz.	1 oz.
Second Class Newspapers, Periodicals	1c.	7 an	4.04 oz.	4 oz.
Third Class Books, Circulars	1c.	4 an	2.31 oz.	2 oz.
Fourth Class Merchandise	1c.	2 an	1.16 oz.	1 oz.

ATMOSPHERIC PRESSURE.

New.	Equivalent.	Old.
40 *ad* per *sqin*	40.83 *ad* per *sqin*	14.75 lbs. per sq. inch.

STEAM PRESSURE.

New.	Equivalent.
0.15 *al* per *sqin*	5.4 lbs. per sq. inch
0.30 *al* per *sqin*	10.8 lbs. per sq. inch
1.00 *al* per *sqin*	36.1 lbs. per sq. inch
2 00 *al* per *sqin*	72.2 lbs. per sq. inch
3.00 *al* per *sqin*	108.3 lbs. per sq inch
4.00 *al* per *sqin*	144.4 lbs. per sq. inch
5.00 *al* per *sqin*	180.5 lbs. per sq. inch
6.00 *al* per *sqin*	216 6 lbs. per sq. inch
7.00 *al* per *sqin*	252.7 lbs. per sq. inch
8.00 *al* per *sqin*	288.8 lbs. per sq. inch
9.00 *al* per *sqin*	324.9 lbs. per sq. inch
10.00 *al* per *sqin*	361.0 lbs. per sq. inch

ALLOWED PRESSURE ON MASONRY.

Kind.	New.	Equivalent.
Brickwork	2.80 *al* per *sqin* to 4.20 *al* per *sqin*	101.1 lbs. per sq. inch to 151.6 lbs. per sq. inch
Stonework	7.00 *al* per *sqin* to 8.30 *al* per *sqin*	252.7 lbs. per sq. inch to 299.6 lbs. per sq. inch

LOADS AND PRESSURES.

The following are loads or pressures expressed in *al* per *sqid* with equivalent values in pounds per square foot, and will suffice to cover wind pressures, snow loads and the usual dead and live loads in common use among engineers and architects:

Al per Sqid.	Pounds per Sq. Foot.	Al per Sqid.	Pounds per Sq. Foot.
0.10	5.2	2.00	104.0
0.20	10 4	3.00	156.0
0.30	15 6	4 00	208.0
0.40	20.8	5.00	260.0
0.50	26.0	6.00	312.0
0.60	31.2	7.00	364 0
0.80	41.6	8 00	416.0
1.00	52.0	10.00	520.0

WEIGHTS OF SUBSTANCES.

Substance.	Al per Cubid.	Pounds per Cubic Foot.
Aluminum	2.60	162.0
Brickwork	1.80	112 0
Carbon	3.40	211.0
Cement (Portland)	1.40	90.0
Cement (Natural)	0.90	56.0
Coal	0.90	58.0
Copper	8.90	555.0
Earth	1.50	95 0
Gold	19.34	1204 0
Granite	2.70	170 0
Iron (Cast)	7.20	450 0
Iron (Wrought)	7.70	480.0
Lead	11.36	709.0
Mercury	13.50	842.0
Oak (Live)	0.95	59.0
Pine (White)	0.40	25.0
Pine (Yellow)	0 70	45.0
Platinum	21.53	1343 0
Sandstone	2.40	151.0
Snow (freshly fallen)	0 20	12.0
Snow (wet compact)	0.80	50.0
Silver	10.50	655.0
Steel	7.85	490.0
Water	1.00	62.4

Note.—To reduce from pounds per cubic foot to *al* per *cubid*, multiply by 0.01603.

To reduce from *al* per *cubid* to pounds per cubic foot, multiply by 62.38.

The specific gravity of any substance is equal to its weight in *al* per *cubid*.

ALLOWED FIBER STRESSES FOR WOODEN BEAMS.

New.	Equivalent.
20 *al* per *sqin*	722 lbs. per sq. inch
25 *al* per *sqin*	953 lbs. per sq. inch
30 *al* per *sqin*	1083 lbs. per sq. inch
35 *al* per *sqin*	1264 lbs. per sq. inch
40 *al* per *sqin*	1444 lbs. per sq. inch
45 *al* per *sqin*	1625 lbs. per sq. inch

ALLOWED STRESSES ON RIVETS.

Shear.	
New.	Equivalent.
16 *al* per *sqin* to 32 *al* per *sqin*	5,780 lbs. per sq. inch to 11,550 lbs. per sq. inch

Bearing.	
New.	Equivalent.
32 *al* per *sqin* to 64 *al* per *sqin*	11,550 lbs. per sq. inch to 23,100 lbs. per sq. inch

EXTREME FIBER STRESSES ON PINS.

New.	Equivalent.
40 *al* per *sqin* to 70 *al* per *sqin*	14,440 lbs. per sq. inch to 25,270 lbs. per sq. inch

ULTIMATE STRENGTH PER SQIN OF STEEL.

Kind.		New Limit.	Precise Equiv.	Old Limit.
Rivet	min.	1,300 *al*	46,930 lbs.	48,000 lbs.
	max.	1,600 *al*	57,760 lbs.	58,000 lbs.
Soft	min.	1,400 *al*	50,540 lbs.	52,000 lbs.
	max.	1,700 *al*	61,370 lbs.	62,000 lbs.
Medium	min.	1,600 *al*	57,760 lbs.	60,000 lbs.
	max.	1,900 *al*	68,590 lbs.	70,000 lbs.

The weight of floors for railroad bridges, now assumed at 400 pounds per linear foot, would become 10 *al* per *id*, equal to 433 pounds per linear foot.

The equivalent uniform loads for Cooper's heaviest engine, which vary from about 9000 pounds to 4000 pounds per linear foot, would be assumed at from 200 *al* to 100 *al* per *id* or from 8666 pounds to 4333 pounds per linear foot.

For the inch-pound we would substitute the *in-al* and the equivalents would be:

1 inch-pound, 0.0277 in-al.
1 in-al, 36.1 inch-pounds.

For the foot-pound we would substitute the *id-al* and the equivalents would be:

1 foot-pound, 0.03324 id-al.
1 id-al, 30.084 foot pounds.

A horse power, now assumed at 33,000 foot-pounds, would equal 1.097 *id-al*. A new unit of work, 1000 *id-al*, equal to 30,084 foot-pounds, would undoubtedly be assumed.

The equivalent heat unit now in use is assumed at 772 foot-pounds and represents the amount of energy necessary to raise the temperature of one pound of water one degree, Fahrenheit. A new heat unit based on the Centigrade thermometer would be adopted and would equal 1668 *id-ad*. In other words a weight of 1668 *ad* falling through a space of one *id* would create the energy necessary to raise the temperature of one *ad* or ten *cubin* of water one degree Centigrade.

As already stated, the changes in linear, surface and ordinary cubic measure are very quickly comprehended. Two hundred *cubin*, fifty *cubin* and twenty-five *cubin* would soon come to be recognized as respective approximate equivalents of the liquid gallon, quart and pint. Likewise, two *cubid* as the approximate equivalent of a bushel and one *ad* as approximately one-third of a pound. It would probably be advisable to adopt one more term, *ar*, equal to one-thousandth part of one *an*, for the convenient designation of the weight of such drugs as strychnine, morphine, etc.

For the measure of temperatures the Centigrade thermometer should be, and undoubtedly soon will become. the standard for all countries, and a uniform decimal system of coinage will follow as a natural result the rapidly increasing closer commercial relationship of the nations; but, as far as the question of weights and measures is concerned, the *inidikil system* and six settings of the slide rule will "make the whole world kin."

It was George William Curtis who said, "Progress begins with the minority. It is completed by persuading the majority, by showing the reason and advantage of the step forward, and that is accomplished by appealing to the intelligence of the majority."

OFFICIAL DUTY TESTS OF PUMPING ENGINES NOS. 9 AND 10, HIGH-SERVICE STATION NO. 3, ST. LOUIS WATER WORKS, FEBRUARY 15-16 AND 26-27, 1900.

By Nils Johnson.

[Read before the Engineers' Club of St. Louis, June 13, 1900.*]

The purpose of this paper is to give a brief summary of the results obtained and the methods employed during the official duty tests of two 15,000,000-gallon triple-expansion pumping engines, designed and built by the Edw. P. Allis Company, of Milwaukee, for the Water Works of the city of St. Louis.

The pumping engines are of the vertical type, a single-acting plunger being located under each of the three cylinders. They are built up entirely of metal, being self-contained, and rest on a natural rock foundation. The depth of the pit is 28 feet and the total height, from foundation to top of steam cylinders, is 63 feet 2 inches. The total weight of each engine is 1,425,500 pounds.

The experts conducting these tests were Edward Flad, Water Commissioner of the city of St. Louis; the writer, in charge of the Construction Department of the St. Louis Water Works, and Arthur West, of the Edw. P. Allis Company, of Milwaukee. A trained crew of fifteen observers, all employes of the Water Department, took part in these tests. Eleven of them were employed as assistant engineers and draftsmen in the construction department, water works extension and the water distribution system of the water works. All of the observers, except three, have taken part in previous bonus duty tests of the pumping engines of the St. Louis Water Works, and all were well qualified for the work. The Edw. P. Allis Company had two men present besides their expert.

The specifications and the contract for these engines contain certain stipulations relating to the duty, the bonus and forfeiture as follows,—viz:

"Article 162. For the purpose of determining the efficiency of the engines furnished under this contract, there shall be a duty test of twenty-four hours' continuous run for each engine. These tests shall be conducted by the Water Commissioner.

"Article 163. The water of condensation from all steam jackets and reheaters shall be gathered and its weight carefully determined, and it shall be charged against the engines during all of the duty tests.

*Manuscript received July 14, 1900.—Secretary, Ass'n of Eng. Socs.

"Article 164. The total weight of water fed to the boilers, during the tests, shall be considered the amount of steam used, when corrected for entrainment.

"Article 165. Steam used for running the boiler feed pumps during the duty tests will be charged against the engines.

"Article 167. The head (h) to be inserted into the formula for computing the duty of the engines during the tests shall be ascertained by attaching a gauge to the discharge pipe, close to where it turns into and runs through the foundation walls of the pit, and by the elevation of the water in the wet well.

"The party of the first part hereby agrees that the pumping engines furnished under this contract shall perform, during a running test of twenty-four hours, a duty of 135,000,000 foot pounds per 1000 pounds of dry steam.

"The party of the first part further agrees that in case either engine fails to perform a duty of 135,000,000 foot pounds per 1000 pounds of steam, during the duty tests of twenty-four hours, it will pay to the party of the second part, as an agreed measure of damage for lack of efficiency of the engine, in the ratio of $2000 for each 1,000,000 foot pounds which the duty falls below 135,000,000.

"In case either engine exceeds, during the twenty-four hours' duty test, an average duty of 135,000,000 foot pounds per 1000 pounds of steam, the party of the second part agrees to pay to the party of the first part, as a reward for the superior efficiency of the engine, an amount to be in the ratio of $1000 for each 1,000,000 foot pounds which the duty exceeds 135,000,000."

The main object of the tests, as set forth by the foregoing, being that of accurately determining the duty upon which to base the payment of forfeiture or bonus, the duty formula and the quantities from which the bonus-duty was figured will first be exhibited,—viz:

$$\text{Duty} = \left(\frac{\pi d^2 \; 3 s \; w \; h \; r}{4 \times 144} - \left[\frac{e \; \pi d^2 \; 3 s \; w \; h \; r}{4 \times 144} + P h + F H \right] \right) \frac{1000}{T}$$

Where

	No. 9 Eng.	No. 10 Eng.
d = diameter of the plungers, in.........	29½	29½
s = stroke of the plungers, ft. (3 single-acting)	6	6
w = weight of one cubic foot water, lbs.	62.42	62.42
h = head pumped against, ft...........	293.1806	292.1189
r = revolutions, in 24 hours	23,716	23,659.5
e = slip of the pump valves, per cent...	0.4	0.4
P = leakage of packings of the plungers, lbs.	15,846	51,201

	No. 9 Eng.	No. 10 Eng.
F = total water fed to boilers, and pumped into tanks Nos. 6 and 7, by pump run by engines, lbs.	218,410	215,468
H = deficiency in head pumped against by boiler feed pump, ft.	$\frac{144 \times 47}{62.27}$	$\frac{144 \times 59.67}{62.27}$
T = dry steam furnished to the engine, by the boiler room record, lbs.	209,699	205,270
$\frac{\pi d^2\ 3s\ w\ h\ r}{4 \times 144}$ = ft. lbs. in 24 hours.	37,080,408,380+	36,858,109,558+
$\frac{e\ \pi d^2\ 3s\ w\ h\ r}{4 \times 144}$ = ft. lbs. loss by slip.	148,321,633+	147,432,438+
P h = ft. lbs. loss by plunger packing.	4,645,739+	14,956,779+
F H = ft. lbs. deficiency in work done by feed pump	23,739,518+	29,731,885+
Duty, per 1000 lbs. of dry steam, ft. lbs.	175,984,156	178,615,389
Duty required by the contract, ft. lbs.	135,000,000	135,000,000
Bonus earned by the builders	$40,984.15	$43,615.38

It will be noticed, in the formula of the bonus-duty, that deductions have been made for losses by the slip of the pump valves, and the leakage of water through plunger packings and deficiency of head pumped against by the boiler feed pump. These losses amount in engine No. 9 to 48-100ths of 1 per cent., and in engine No. 10 to 52-100ths of 1 per cent., of the total work by plunger displacement.

It was impossible to ascertain the percentage of slip directly during the tests, on account of pumping directly into a high-pressure system. The percentage was deduced from slip tests of low-service engines 6, 7, 8 and 9 at Chain of Rocks; these pumps have valves similar to those of engines 9 and 10.

The instruments and apparatus used in the tests were carefully tested and compared with reliable standards before the tests, and several of them also after the tests.

The weighing scales were adjusted and tested to United States standard weights by the Inspector of Weights and Measures of the city of St. Louis.

The specific gravity of the mercury used in the mercury column was determined by John F. Wixford, chemist of the St. Louis Water Works, and found to be 13.5895 at 70° F. The mercury was completely volatilized when subjected to red heat, thus showing absence of non-volatile metals.

An extra revolution counter was provided and put beside the regular revolution counter of the engine. Both registered equally throughout the tests.

For ascertaining the elevation of the water in the wet well*

*The average height of the water in the wet well was 11.67 feet in No. 9 and 13.56 feet in No. 10 test above top surface of the diaphragm of suction

(*i.e.*, the suction head) a float gauge was attached to the suction pipe in the engine room. This gauge was located between the wall of the wet well and the induction pipe of the circulating water of the surface condenser. For comparison and as a safeguard a gauge glass was put in the standpipe of the float gauge.

The relative elevations above city datum of the graduations of the mercury column and the gauges of the wet well were determined by precise leveling.

All pump valves were examined and tested by water pressure, and were perfectly tight before the test.

The circumference of the plungers was measured at the top, bottom and middle by a standard Chesterman steel tape. The diameters were averaged from these measurements, which were verified by calipering the plungers at the same places; the diameters thus obtained checked within 5-100ths of 1 per cent.

The stroke of the plungers was also measured by a standard Chesterman steel tape, by putting the cranks on dead centers and scribing lines on the crosshead shoes and the guides; the pressure of water on the plungers was turned off in order to guard against errors due to lost motion of the journals.

The thermometers were compared with a Hick's standard thermometer, verified at the Kew observatory.

The Crosby indicators, with the Sargent's electro-magnetic attachment for taking cards simultaneously, were used. The cards were dotted by a circuit breaker operated by hand. The dotting was expected to eliminate the pencil friction almost entirely. Nine indicators were operated simultaneously by a current of 110 volts and 2 amperes taken direct from the dynamo. At the end of every hour indicator cards were dotted continuously for one minute, and simultaneously the mercury column was read every ten seconds. The average head obtained from these readings was used in figuring the delivered horse power.

Exhibits A and B are appended for the purpose of showing the totals of the weighings of the water in the engine room and boiler room, and how closely these weighings check.

The checking of the lowering of the boiler levels is shown in Exhibit C.

Exhibit A shows that the boiler room record gives less steam chargeable to the engines than the engine room records, by 484 pounds for No. 9, and 111 pounds for No. 10 test. These discrepancies are probably due in the main to errors introduced in the readings of the gauge glass and to the fluctuations of the water level in the boilers, thus making a fictitious water level, affecting

the results with 22-100ths of 1 per cent. in No. 9 and 5-100ths of 1 per cent. in No. 10 test.

The water level in the gauge glass of the boilers was read a certain length of time at the start and ending of the tests, and the feed pump (C) kept running at a speed required to deliver back to the boilers simultaneously the exact weight of water sent away to the engines in the shape of steam.

The checking shown in Exhibit C points to the lowering of the water level of the boilers that should have taken place, assuming that the boilers and pipe connections leaked at the same rate as in the twenty-four-hour leakage test.

Exhibit B shows that the difference in the weighings in the tanks of the engine room and the boiler room was only 101 pounds during the test of No. 9 and 45 pounds at No. 10 test.

A special check sheet was kept complete every hour of the tests, checking the weighings of the water in the engine room and the boiler room, and also the amount of feed water put into the boilers and the steam sent away.

EXHIBIT A.

Boiler Room Record.

		No. 9 Eng.	No. 10 Eng.
1.	Water on hand in tank No. 6 at start of test, lbs.	310	814
2.	Total water weighed in tanks Nos. 6 and 7 during test, lbs.	218,419	215,468
3.	Total water weighed in tank No. 8 during test, lbs.	1,704	1,704
4.	Boiler levels lowered during test, lbs.	715	1,073
5.	Total lbs.	221,148	219,059
	Deduct.		
6.	Water weighed in tank No. 5, lbs.	7,915	9,968
7.	Leakage during 24 hours of boilers and pipe connections, lbs.	1,716	1,704
8.	Steam blown through calorimeter, lbs.	505	456
9.	Water on hand in tank No. 6 at end of test, lbs.	836	828
10.	Entrained water in steam (by the calorimeter), lbs.	477	824
11.	Total lbs.	11,449	13,780
12.	Dry steam chargeable to engine (Items 5-11), and from which bonus-duty was figured, lbs.	209,699	205,279
13.	Dry steam by engine room record (Items 16 + 17 + 18 — 10), lbs.	210,183	205,390
14.	Diff. in dry steam by boiler and engine room record (Items 12-13), lbs.	— 484	— 111

EXHIBIT B.

Engine Room Record.

		No. 9. Eng.	No. 10 Eng.
15.	Water on hand in tank No. 2 at start of test, lbs.....	700	575
16.	Total water weighed in tanks Nos. 1 and 2 during test, lbs.	180,258	174,659
17.	Total water weighed in tank No. 3 during test, lbs...	25,130	25,691
18.	Total water weighed in tank No. 4 during test, lbs..	5,272	5,864
19.	Total water weighed in tank No. 5 during test, lbs...	7,915	9,968
20.	Total lowering of level of hot well, lbs.	810	270
21.	Total lbs.	220,085	217,027
	Deduct.		
22.	Water on hand in tank No. 2 at end of test, lbs......	635	600
23.	Water on hand in tank No. 3 at end of test, lbs......	360	353
24.	Water on hand in tank No. 4 at end of test, lbs......	225	237
25.	Water on hand in tank No. 5 at end of test, lbs......	345	414
26.	Total lbs.	1,565	1,604
27.	Water sent from engine room to tanks Nos. 6 and 7 (Items 21-26), lbs.	218,520	215,423
28.	Water weighed in tanks Nos. 6 and 7 (Item 2), lbs..	218,419	215,468
29.	Diff. between boiler room and engine room weighings (Items 27-28), lbs.	+ 101	— 45

EXHIBIT C.

		No. 9 Eng.	No. 10 Eng.
30.	Steam blown through the calorimeter, lbs.	505	456
31.	Water on hand at end of test in tanks No. 2, 3, 4 and 5, lbs.	1,565	1,604
32.	Water on hand at end of test in tank No. 6, lbs......	836	828
33.	Total lbs.	2,906	2,888
34.	Hot well level lowered, lbs.	810	270
35.	Water on hand in tank No. 6 at start of test, lbs.....	310	814
36.	Water on hand in tank No. 2 at start of test, lbs....	700	575
37.	Total lbs.	1,820	1,659
38.	Actual weight of water in lbs. the boiler level should have lowered (Items 33-37), lbs.	1,086	1,329
39.	Computed weight of water lowered in the boilers by the gauge glass, lbs.	715	1,073
40.	Diff. between actual and observed weights (Items 38-39), lbs.	371	156

Fig. 1 shows a trimetric projection of the piping and the weighing scales used in the tests.

Every possible precaution was taken to guard absolutely against admitting foreign water or steam to the system, by disconnecting the pipes or by inserting blind flanges in all pipes not

properly belonging to the system. All drippings and drains were taken care of by suitable piping.

All the steam having passed through the cylinders, jackets and reheaters of the engines, being condensed, was caught and weighed in tanks 1, 2, 3 and 4. The entrained water of the steam removed by the Sweets separator passed through the trap A, and the water of condensation in the steam main of engines 9 and 10 passed through the trap B, thence through a cooling coil and into weighing tank No. 5.

The jacket water of the low-pressure cylinder was also passed through a cooling coil before being weighed. The temperature of the water, when reaching the weighing tanks 3, 4 and 5, averaged 135° F. Tanks 3, 4 and 5 were covered in order to catch any possible evaporation. All the water weighed in tanks 1, 2, 3, 4 and 5 was turned into the hot well, from which it was taken by the feed pump, attached to the engine, and pumped through the filter and thence to tanks 6 and 7 in the boiler room. Tank 8 in the boiler room weighed 71 pounds of cold water each hour, to supply the amount of leakage of the boilers and piping; this being the hourly average weight of water leaking through the boilers and piping, as determined by a leakage test of twenty-four hours' duration, made before the engine tests.

Tanks 6 and 7 in the boiler room emptied into tank 9, which was connected to the suction pipe of the independent feed pump C. Tank 9 was provided with a hook gauge. The water in this tank was brought to the level of the hook gauge at the end of every hour by careful regulation of the speed of the feed pump C.

The leakage water of the packings of the main pump plungers was weighed every ten minutes throughout the tests.

The springs of the steam indicators were calibrated (see Fig. 2) by attaching them directly in their respective positions at the bottom of the steam cylinder C. The three-way cock A was turned in communication with the steam cylinder, and the piston of the indicator was kept in motion for some time, or until it was thought that all parts of the indicator had acquired the temperature due to the actual working conditions. In the meantime the steam pressure in the vessel 2 was regulated by the valve H and the drain valve L to correspond to pressures in the steam cylinder during the test.

The pressure in the vessel 1 was always carried 5 pounds higher than in the vessel 2; in order to facilitate the adjustment of the pressure in this vessel the pressure in vessel 1 was regulated by valve J and the drain valve M. Gauges K and D were carefully tested by a Crosby gauge-testing machine.

Weights were applied on the disk of the plunger Q to correspond to a given pressure. The plunger was then put in rotation by a jet of compressed air from nozzle N impinging on the vanes O of the disc. The air jet was shut off as soon as the plunger Q had attained a certain speed; the inertia kept the plunger and weights revolving. At the moment when it was found that the system was rotating in equilibrium axially, the three-way cock A was turned in communication with the vessel 2, and in turning the cock an electric circuit was closed by a projection P of the plug-cock A. The electric current passing through the solenoid F disengaged the trigger R, allowing the tension of the drum spring to rotate the indicator-drum an arc of about 43°. Simultaneously the pencil was held against the card by the solenoid G and the line corresponding to the pressure in vessel 2 was drawn.

It was found that more uniform and accurate results were obtained by gently tapping the working cylinder of the indicator, in order to avoid injurious effects of inertia and possible sticking of the piston of the indicator.

To calibrate a spring for a certain given pressure (say 80 pounds) 10 lines were traced, 5 lines with an upward floating tendency of the plunger Q and 5 lines with a downward tendency. The average of these lines was used to determine the calibration of the spring. It was not possible to catch the plunger rotating at an absolute axial equilibrium, and this method was thought to eliminate errors more completely than only drawing one line. An atmospheric line was traced for each pressure line.

Mr. Arthur West, the expert for the Edw. P. Allis Company, is the originator of this method of calibration. The arrangement of the details was worked out by Walter S. Brown, First Assistant Engineer of the Construction Department of the St. Louis Water Works.

Fig. 3 shows an apparatus for testing indicator springs, used previously by the Construction Department of the St. Louis Water Works. It is thought that the apparatus and method shown in Fig. 2 are conducive to more correct results.

The springs of the pump indicators were calibrated by a Crosby dead weight testing apparatus.

The water in the tanks 1 and 2 was weighed every 5 minutes, in tank 3 every 20 minutes, in tanks 4 and 5 and 8 every hour, in tanks 6 and 7 every 6 minutes.

The revolution counters, gauges and thermometers were read every 30 minutes. The gauge glasses of the boilers were read every 15 seconds for 5 minutes at the end and start of the tests.

The mercury column was read every 5 minutes and the wet well gauge every 10 minutes. The entrained water in the steam was determined by the Carpenters' separating calorimeter located close to the throttle.

The coal burned during the tests was weighed as it was brought into the boiler room on charging cars, and the ashes were also carefully weighed when leaving the boiler room. Fig. 11 shows the arrangement of the boiler room and the engine room of the pumping station.

The boiler tests are not indicative of the best boiler performance, as twice the required boiler capacity to run one engine was kept under fire during the tests. This was done owing to the difficulty of cutting out one single boiler and also in order to avoid irregular pressure of the steam while cleaning the fires. Consequently it is clear that the duty obtained per 100 pounds of coal is much lower during the tests than under ordinary working conditions.

The water evaporated per pound of coal under actual conditions was 5.45 pounds for No. 9 and 5.35 pounds for No. 10 test, giving an efficiency of 54.5 and 53.46 per cent. respectively; whereas, the official twenty-four-hour test of these boilers run February 10, 1898, gave an efficiency of 72.6 per cent. from Southern Illinois bituminous coal of a calorific value of 11,414 B. T. U. and 10.6 per cent. ashes.

Fig. 4 shows a front view of the pumping engines. It will be noticed that all the eccentrics of the valve motions are run by a lay shaft, located immediately above the second gallery floor.

There are two eccentrics operating the valves of each cylinder, one for the admission and one for the exhaust. The cut-off of the high-pressure cylinder is controlled by a centrifugal governor, the cut-off of the intermediate cylinder is adjusted by hand. The low-pressure cylinder is provided with a fixed cut-off.

The admission and the exhaust valves of the high-pressure cylinder and the admission valves of the intermediate cylinder are of the Corliss type, and are located in the heads of the cylinders. The exhaust valves of the intermediate and the admission and exhaust valves of the low-pressure cylinder are all of the poppet valve type with single seats. These valves are operated by cams or curved levers.

The pump valves are of medium hard rubber 3½ inches outside diameter. There are 7 valve cages in each of the suction and discharge diaphragms. Each cage is provided with 24 valves on the sides and 4 valves on top, as shown in Fig. 5. The aggregate

free area of 196 valves is 5.98 square feet, and the area of one plunger is 4.74 square feet. The suction and discharge pipes are 36 inches in diameter.

The air pump, the feed pump and the air compressor are permanently attached to the plunger of the low-pressure cylinder, and were in operation continuously during the tests.

The circulating water was taken from the suction pipe, and, after having passed through the tubes of the condenser, was returned to the suction pipe again, as shown in Fig. 6.

Graphical logs of the hourly average quantities are shown in Figs. 7 and 8, and combined cards in Figs. 9 and 10.

The data of the indicator cards and the leading dimensions of the engines, with the results computed from the quantities obtained in the tests, are given herewith, and also a "Table of Results of Tests of Pumping Engines"; this table is a partial extract from a paper, No. 833, by Prof. R. H. Thurston in the "Transactions of the American Society of Mechanical Engineers," December, 1899, Vol. XXI.

Indicator Card Data.

	9		10	
	Top.	Bottom.	Top.	Bottom.
Area of high-pressure piston....	907.92	874.32	907.92	874.32
Area of intermediate piston....	3,019.1	2,985.5	3,019.1	2,985.5
Area of low-pressure piston...	6,647.6	6,614	6,647.6	6,614
High-Pressure Cards.				
Scale of spring (manufacturer's)	80	80	80	80
Scale of spring (calibrated by Const. Dept.)	78.83	77.08	78.83	77.08
Initial pressure (absolute)......	141.72	140.87	141.35	140.26
Cut-off pressure (absolute)	141.48	140.63	141.11	138.7
Release pressure (absolute).....	42.064	45.155	42.177	41.207
Per cent. of cut-off	31.11	31.54	32.45	30.38
Mean effective pressure	53.6	54.45	55.5	52.45
Indicated horse power	145.6	142.4	149.3	136.9
Indicated horse power (total)..	288		286.2	
Intermediate-Pressure Cards.				
Scale of spring (manufacturer's)	20	20	20	20
Scale of spring (calibrated by Const. Dept.).............	19.675	19.446	19.675	19.446
Initial pressure (absolute)	40.62	40.51	41.37	41.03
Cut-off pressure (absolute)	32.91	33.37	33.56	33.84
Release pressure (absolute)	10.793	11.132	10.36	11.31
Per cent. of cut-off	36.38	36.41	32.92	34.21
Mean effective pressure	12.83	13.13	13.55	14.27
Indicated horse power	116.0	117.4	122.2	127.3
Indicated horse power (total)..	233.4		249.5	

Low-Pressure Cards.

Scale of spring (manufacturer's)	10	10	10	10
Scale of spring (calibrated by Const. Dept.)	9.877	9.380	9.877	9.380
Initial pressure (absolute)	12.64	12.07	11.56	11.35
Cut-off pressure (absolute)	8.06	8.05	8.3	8.4
Release pressure (absolute)	3.07	3.87	4.16	3.07
Per cent. of cut-off	47.22	45.79	49.7	45.5
Mean effective pressure	7.36	7.32	6.06	6.47
Indicated horse power	146.4	144.9	138.2	127.7
Indicated horse power (total)	291.3		265.9	
Total horse power, 3 cylinders	812.7		801.6	

REPORT OF DUTY TESTS OF HIGH-SERVICE ENGINES NOS. 9 AND 10.

General Data.

1.	No. of engine	9	10
2.	Date of test	Feb. 15 16.	Feb. 26-27.
3.	Duration of test, hrs	24	24
4.	Type of engine	Triple-expansion.	
5.	Dia. of H. P. cyl. in.	34	34
6.	" I. P. "	62	62
7.	" L. P. "	92	92
8.	" piston rods (2 for each cyl.), in.	4⅝	4⅝
9.	Dia. of plungers, in.	29½	29½
10.	" feed pump, in.	2¾	2¾
11.	" air compressor, in.	3	3
12.	" air pump (single-acting), in.	26	26
13.	Stroke of all cyls., plungers and pumps, ft.	6	6
14.	No. of plungers	3	3
15.	Kind of "	Single-acting.	
16.	Clearance of H. P. cyl. (top), per cent	1.050	1.050
17.	Clearance of H. P. cyl. (bottom), per cent	1.172	1.172
18.	Clearance of I. P. cyl. (top), per cent	0.374	0.374
19.	Clearance of I. P. cyl. (bottom), per cent	0.55	0.55
20.	Clearance of L. P. cyl. (top), per cent	0.276	0.276
21.	Clearance of L. P. cyl. (bottom), per cent	0.451	0.451
22.	Cooling surface of condenser, sq. ft.	2,102	2,102
23.	Cooling surface of condenser, per I. H. P., sq. ft.	2.59	2.62
24.	Heating surface of 1st rec. coil, sq. ft.	123	123
25.	Heating surface of 2d rec. coil, sq. ft.	170	170
26.	Vol. of H. P. cyl. (displacement) top, cu ft.	37.83	37.83
27.	Vol. of I. P. cyl. (displacement top, cu. ft.	125.79	125.79

GENERAL DATA (Continued).

28. Vol. of L. P. cyl. (displacement) top, cu. ft	276.98	276.98
29. Vol. of 1st rec., cu. ft	184	184
30. " 2d " "	365	365
31. Ratio of areas of H. P. cyl. to I. P. cyl.	1 to 3.32	1 to 3.32
32. Ratio of areas of I. P. cyl. to L. P. cyl.	1 to 2.2	1 to 2.2
33. Ratio of areas of H. P. cyl. to L. P. cyl.	1 to 7.32	1 to 7.32
34. Ratio of volumes of H. P. cyl. to 1st rec.	1 to 4.87	1 to 4.87
35. Ratio of volumes of I. P. cyl. to 2d rec.	1 to 2.9	1 to 2.9
36. Ratio of volumes of 1st rec. to 2d rec.	1 to 1.98	1 to 1.98

PRESSURES.

37. Steam pressure (initial) in H. P. cyl. by cards, lbs	126.9	126.2
38. Steam pressure in boiler room by gauge, lbs	129.7	130.2
39. Steam pressure in 1st rec. by cards, lbs	26.2	26.6
40. Steam pressure in 2d rec. by cards (Vac.), lbs	1.8	3.2
41. Steam pressure H. P. jacket, lbs.	Initial.	Initial.
42. " " I. P. " by gauge, lbs	Second Rec.	Coil.
43. Steam pressure L. P. jacket by gauge (Vac.), lbs.	2.36	0.61
44. Steam pressure 1st rec. coil by gauge	H. P. Jacket.	Pressure.
45. Steam pressure 2d rec. coil	52.3	52
46. Vacuum by gauge, lbs	14.64	14.5
47. " " cards, "	14.01	14.04
48. Barometer, lbs	14.41	14.64
49. " in	29.45	29.93

TEMPERATURES IN DEGREES F.

50. Water pumped	36	35
51. Drain from 2d rec. (Therm. close to outlet)	200.5	197.2
52. Drain from L. P. jacket (Therm. close to outlet)	192.7	201
53. Water fed to boiler	76	80
54. Water discharged from air pump	67.5	67
55. Circulating water of condenser (in)	36	35
56. Circulating water of condenser (out)	55	51
57. Air in engine room	67	73
58. Air outside	15	25
59. Exhaust steam in pipe near L. P. cyl.	97.3	98
60. Steam (initial)	325.7	325.4

Feed Water and Steam.

61. Total water evaporated by boilers (Items 5-9, Exh. A), lbs..	220,312	218,231
62. Total water fed to boilers (Item $5-(4+9)$, Exh. A), lbs......	219,507	217,158
63. Total water fed to boilers per hour $\left(\frac{\text{Item 62}}{24}\right)$, lbs............	9,146.87	9,048.25
64. Total dry steam chargeable to engine by engine room record (Item 13, Exh. A), lbs.........	210,183	205,366
65. Dry steam to engine per hour $\left(\frac{\text{Item 64}}{24}\right)$, lbs....................	8,757.5	8,557.0
66. Quality of steam at throttle, per cent................................	99.773	99.6
67. Total water from surface condenser (Item 16, Exh. B), lbs.	180,258	174,059
68. Average water from surface condenser per hour $\left(\frac{\text{Item 67}}{24}\right)$, lbs.	7,510.8	7,277.5
69. Total water from L. P. jacket (Item 17, Exh. B), lbs...........	25,130	25,691
70. Average water from L. P. jacket per hour $\left(\frac{\text{Item 69}}{24}\right)$, lbs........	1,047	1,070.4
71. Total water from 2d rec. drain (Item 18, Exh. B), lbs..........	5,272	5,864
72. Total water received from engine (Item 67 + 69 + 71), lbs........	210,660	206,214
73. Average water received from engine per hour $\left(\frac{\text{Item 72}}{24}\right)$, lbs.	8,777.5	8,592.2
74. Jacket water of L. P. cyl. $\left(\frac{\text{Item 69} \times 100}{\text{Item 72}}\right)$, per cent.....	11.9	12.45
75. Drain from 2d rec. $\left(\frac{\text{Item 71} \times 100}{\text{Item 72}}\right)$ per cent..............................	2.505	2.845

Pump Data.

76. Total revolutions......................	23,710	23,050.5
77. Revolutions per minute $\left(\frac{\text{Item 76}}{24 \times 60}\right)$	16.47	16.43
78. Piston speed per minute (Item $13 \times 2 \times$ Item 77), ft............	197.04	197.16
79. Displacement of plungers per revolution, lbs....................	5,332.954	5,332.954
80. Displacement of plungers per revolution, gals..................	639.11	639.11
81. Total water pumped, plunger displacement, gals.............	15,157,137	15,121,027
82. Average head (corrected for temp., etc.), ft....................	203.1866	202.1186
83. Total ft. lbs. of work in 24 hrs. plunger displacement (Item 76 × Item 79 × Item 82).......	37,080,408,386	36,858,100,558

Indicator Cards.

84.	Indicated horse power	812.7	801.6
85.	Delivered horse power	779.97	776.27
86.	Total friction horse power (mech. and hyd.)	32.73	25.33
87.	Per cent. friction $\left(\frac{\text{Item 86}}{\text{Item 84}} \times 100\right)$*	4.028	3.16
88.	Total number of expansions from combined cards	33.89	36.06

Summary and Results.

89.	Feed water per I. H. P. per hr., lbs	10.8	10.719
90.	Dry steam per I. H. P. per hr., lbs	10.776	10.676
91.	Feed water per D. H. P. per hr., lbs	11.254	11.069
92.	Dry steam per D. H. P. per hr., lbs	11.228	11.024
93.	Duty per 1000 dry steam $\left(\frac{\text{Item 83} \times 1000}{\text{Item 64}}\right)$, plunger displacement, ft. lbs	176,410,636	179,454,255
94.	Duty per million B. T. U. $\left(\frac{\text{Item 83} \times 1{,}000{,}000}{\text{Item 98}}\right)$, ft.lbs.	155,237,451	158,077,324
95.	B. T. U. per I. H. P. per minute $\left(\frac{\text{Item 98}}{24 \times 60 \times \text{Item 84}}\right)$	204.37	201.06
96.	Mechanical efficiency $\left(\frac{\text{Item 85}}{\text{Item 84}} \times 100\right)$, per cent	95.972	96.84
97.	Thermodynamic efficiency $\left(\frac{42.42}{\text{Item 95}}\right)$, per cent	20.781	21.003
98.	B. T. U. chargeable to engines	238,862,518	233,165,064
99.	Actual efficiency (Item 96 $\times$ Item 97), per cent	19.944	20.339

*Engine No. 9 was operated 5845 hours, making 9,967,800 revolutions, and Engine No. 10 4608 hours, making 7,818,000 revolutions before the official test.

Table of Results of Tests of Pumping Engines.

	No. 9.	No. 10.					
1. Name of designer or builder	E. P. Allis Co.	E. P. Allis Co.	E. P. Allis Co.	E. P. Allis Co.	E. D. Leavitt, Jr.	Lake Erie Eng. Works.	Snow Steam Pump Works.
2. Locality	St. Louis, Mo.		Milwaukee, Wis.	Detroit, Mich.	Chestnut Hill, Mass.	Buffalo, N. Y.	Indianapolis, Ind.
3. Type	Triple Expansion.		Trip. Ex.	Trip. Ex.	Trip. Ex.	Trip. Ex.	Trip. Ex.
4. Extent of jacketing	Barrels and Receivers.		Barrels and Receivers.	Barrels and Receivers.	Barrels, Heads and Receivers.	Barrels and Receivers.	Barrels, Heads and Receivers.
5. Name of experts conducting test	Flad, Johnson and West.		Prof. R. C. Carpenter.	Geo. H. Barrus.	Prof. E. F. Miller.	Geo. H. Barrus and Newcomb Carlton.	Prof. W. F. M. Goss.
6. Capacity, million gals., in 24 hours	15	15	18	24	20	30	20
7. Size of steam cylinders, in.	34, 62, 92 x 72	34, 62, 92 x 72	28, 48, 74 x 60	28, 48, 74 x 60	137.7, 24.37, 39 x 72	37, 63, 94 x 60	29, 52, 80 x 60
8. Size of water plungers, in.	29.5 x 72	29.5 x 72	32 x 60	36 x 60	Double Acting, 17.5 x 48	42 x 60	33 x 60
9. Total heads, lbs.	127.08	126.64	70.4	53.4	59.4	86.1	88.7
10. Piston speed, ft. per minute	107.64	107.16	203.1	209.6	607	207.7	214.6
11. Ratio of volume of L. P. cyl. to volume of H. P. cyl.	7.32	7.32	7.1	7.1	8.3	6.5	7.7
12. Initial pressure by cards	126.9	126.2	121.4	125.2	175.7	167.1	155.6

TABLE OF RESULTS OF TESTS OF PUMPING ENGINES (Continued).

13.	Cut-off press. (above atmosphere), H. P. lbs.	126.64	126.16	118.6	119.4	151.5	152.2	153
14.	Release pressure L. P. cyl. (above zero), lbs.	3.92	4.06	5.3	5.8	6.9	7.4	6.4
15.	Back pressure L. P. cyl. (above zero), lbs.	0.4	0.6	1.6	2.8	1.5	2.2	2.5
16.	Cut-off H. P. cylinder, per cent	31.32	31.41	33.7	33.8	38.4	32.3	31.5
17.	Clearance H. P. cylinder, per cent	1.116	1.116	1.4	1.4	1.5	1.4	1.8
18.	Ratio of expansion by volumes	22.7	23.4	20.4	20.3	21	19.6	23.8
19.	Indicated horse power	812.7	801.6	573.9	573.7	575.7	1185.5	775.5
20.	Friction, per cent	4.028	3.16	9.2	10.2	10.5	5.1	4.6
21.	Dry steam per I. H. P. per hour, including jackets and reheater, lbs	10.776	10.676	11.68	12.52	11.22	12.39	11.26
22.	Per cent. of steam condensed in jackets and reheaters	14.4	15.3	9.2	12.7	17.1	13.7	10.5 est.
23.	Dry steam per I. H. P. per hour, exclusive of jackets and reheaters	9.223	9.021	10.61	10.93	9.3	10.7	10.8 "
24.	Steam accounted for by indicator, H. P. cut-off, lbs	9.0255		9.05*	9.5	8.5*	9.1	8.7*
25.	Cylinder condensation, including jacket and reheater, at cut-off, H. P. cylinder, per cent	16.2		22.5	24.1	24.2	26.6	22.7
26.	M. E. P. referred to L. P. cylinder, lbs	20.62	20.58	21.77	21.03	26.36	27.19	23.65
27.	Duty based on 1,000,000 B. T. U., expressed in million foot pounds	155.2	158.7	137	129.7	141.9	135.4	150.1
28.	Duty based on 1000 lbs. of dry steam, expressed in million foot pounds	176.4	179.4	154	142.4	154.9	152	167.8

* Calculated by G. H. Barrus.

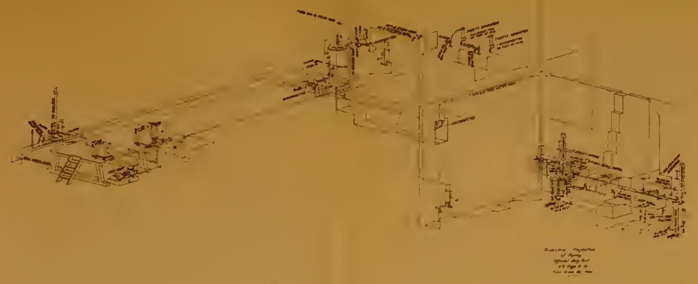

FIG. 1 PIPING, TANKS, ETC.

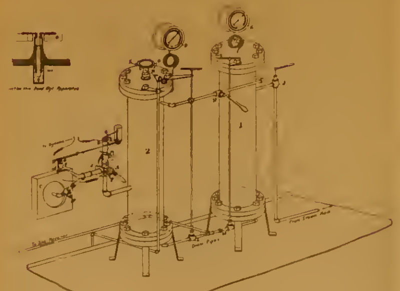

FIG. 2. APPARATUS FOR CALIBRATING INDICATOR.

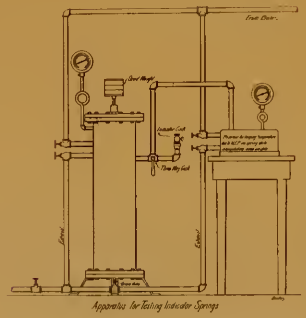

FIG. 3. APPARATUS FOR TESTING INDICATOR SPRINGS.

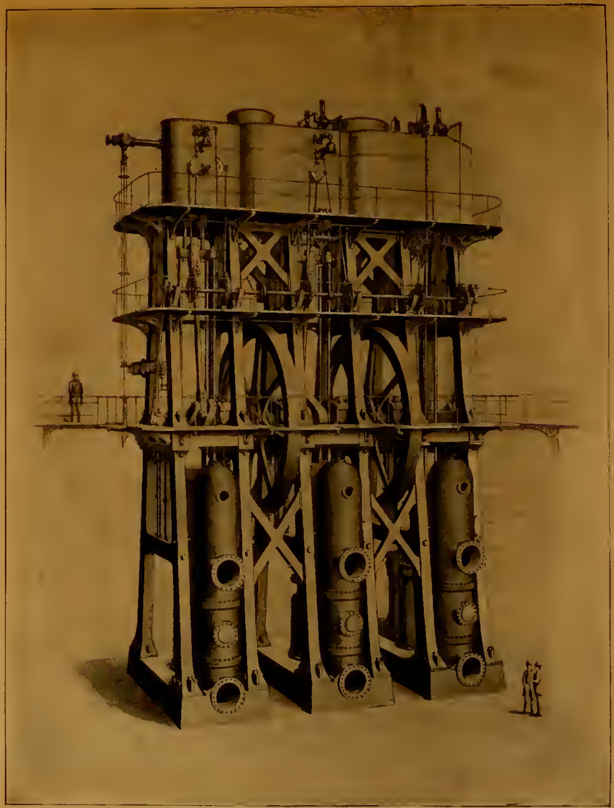

FIG. 4. VERTICAL TRIPLE-EXPANSION HIGH-SERVICE ENGINES.

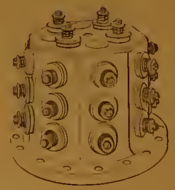

FIG. 5. VALVE CAGE.

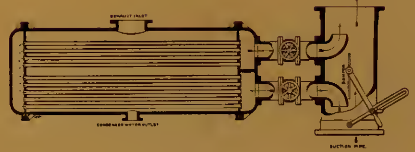

FIG. 6. METHOD OF CIRCULATING WATER THROUGH CONDENSER.

Table of Results of Tests of Pumping Engines (Continued).

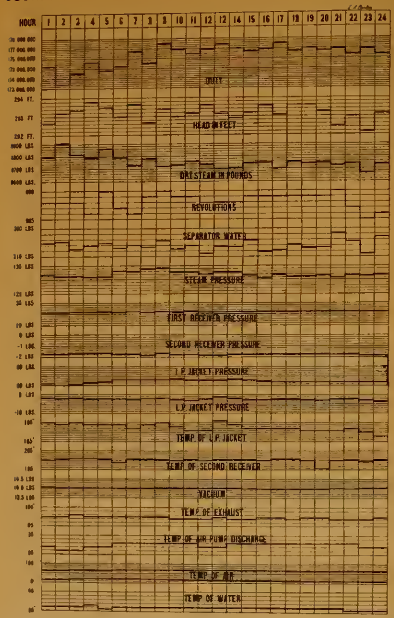

FIG. 7. LOG OF TEST, ENGINE NO. 9.

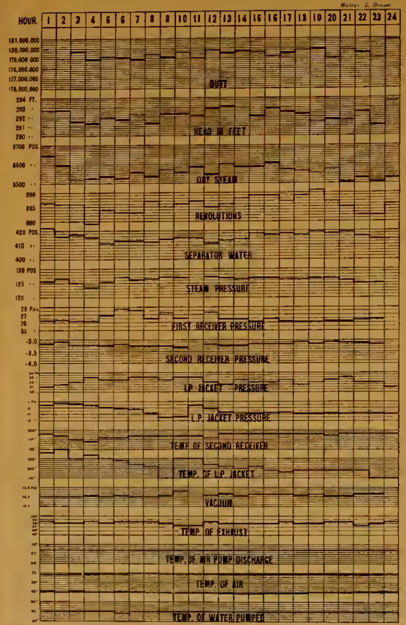

FIG. 8. LOG OF TEST, ENGINE NO. 10.

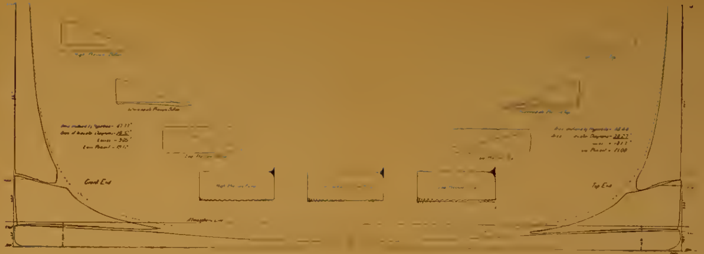

FIG. 9. COMBINED STEAM INDICATOR DIAGRAM, ENGINE NO. 9.

FIG. 10. COMBINED STEAM INDICATOR DIAGRAM, ENGINE NO. 10.

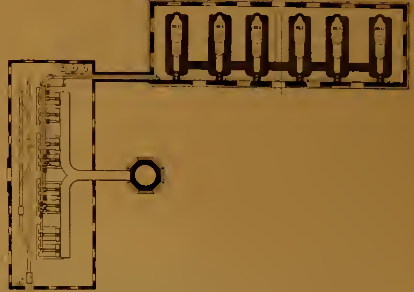

FIG. 11. PLAN OF ENGINE AND BOILER ROOMS.

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THE WATER POWER AT HOLYOKE, MASSACHUSETTS.

BY HORATIO A. FOSTER, MEMBER ENGINEERS' SOCIETY OF WESTERN NEW YORK.

[Read before the Society, June 4, 1900.*]

IN these days of the transmission of power by means of electricity the search for good and reliable water powers has become a sort of engineering fad, and the numbers of them that are exploited and brought to the attention of capitalists is something to be wondered at. Many of them are so far from users of power as to make it discouraging to invest the necessary money, and others are so variable in their flow of water as to make them very unreliable, compelling the installation of an auxiliary steam plant to insure continuity of operation.

Incidentally, it may not be known to all present that the Government, during the census of 1880, caused examinations to be made of nearly all the water courses east of the Mississippi River. The territory was divided into districts, and an expert placed in charge of each. Every important river and stream was examined from its mouth back to its source; each and every fall was described, whether developed or not; the flow of water at the different points was gaged, and many other useful data were reported.

Fifty years ago there were very few large water powers developed, and comparatively little was known of the modern means of using water power. Railroads were new, as were also most of the conveniences with which at the present day we would find it difficult to dispense.

*Manuscript received June 11, 1900.—Secretary, Ass'n of Eng. Socs.

The water power at Holyoke, Mass., was developed more than fifty years ago, and has been in continuous operation ever since. From a very small farming village there has developed one of the strongest and most industrious manufacturing communities in the United States. Although a large portion of the product of Holyoke is fine paper, there are many other products, notably cotton cloth, cotton yarns and spool cotton, one of the largest factories for the manufacture of the latter article being located there.

At Holyoke the Connecticut River, more than 300 miles long, makes an abrupt bend, which is almost a true half-circle. Originally there were rapids around this bend, with a total fall of 60 feet from one end of the semicircle to the other.

In 1847 the Legislature of Massachusetts was petitioned by Thomas H. Perkins, George H. Lyman, Edmund Dwight and others for an act of incorporation for the Hadley Falls Company, "for the purpose of constructing and maintaining a dam across the Connecticut River and one or more locks and canals in connection with said dam; and for creating a water power to be used by said corporation for manufacturing articles from cotton, wood, iron, wool and other materials, and to be sold to other persons and corporations to be used for manufacturing or mechanical purposes, and also for the purpose of navigation." The capital stock was $4,000,000. The Hadley Falls Company purchased the property and franchise of the South Hadley Falls Lock and Canal Company, and land in the region amounting to 1100 acres.*

At this time (1847) there were fourteen houses, a grist mill, one little shop and one cotton mill lying in the region now covered by the city of Holyoke. It is also recorded that a wing dam was built out into the stream in 1831, and a small mill run by the power thus developed.

The first dam was begun in 1847 by building a coffer dam of cribs filled with stone. I quote the following description of the coffer dam from data furnished by a resident of South Hadley Falls:

"The coffer dam was built by loading cribs with stone, gravel, etc., and sinking them about four rods above the line of the great dam. The bed-piece was formed of four stretchers. The sills were very large timbers, 40 or more feet long, which were intended to be bolted to the bedrock, but there was a good deal of blocking up under some of them. In some places it was necessary to blast rock out under them; in other places it was necessary to put blocks

*In 1859 the Hadley Falls Company was succeeded by the present corporation, the Holyoke Water Power Company.

under and use longer bolts. The sills were 6 feet apart from center to center; the posts were framed into the sill and into the stretcher, and each section was raised on its sill like the side of a house or barn. The roof of the dam was covered with 4-inch hemlock planks. All timber and planks were hemlock. The overfall was 12 feet long, of 1-foot timbers, and covered with plank same as the other side of the dam. The crest of the dam was covered with boiler iron in strips 6 to 8 feet long."

This dam was destroyed and washed away the first time it was filled. The event of the completion of the coffer dam in 1848 had been anticipated by the public, and special trains were run to accommodate those who wished to see the first flow of water over it. The pond filled very slowly, and it was three o'clock in the afternoon when the dam gave way under the strain. The structure broke from its foundations, turned over and, with the exception of 75 feet at one end and 150 feet at the other, was swept downstream by the great volume of water.

There was some interesting reading about this event at the time, and, without burdening this paper with much of it, I think the following series of telegrams sent at the time by a Mr. Davis, who was interested in the corporation, will be fully appreciated. The dispatches were in the order given, but only the last one is vouched for as being verbatim:

"10 A.M.—The gates were just closed, and the water is filling behind the dam."

"12 M.—The dam is leaking badly."

"2 P.M.—The stones of the bulkhead are giving way to the pressure."

"3.20 P.M.—Your old dam has gone to hell by way of Willimansett."

Even to-day the destruction of so large a piece of work would be very discouraging, but the discouragement seems to have been very short-lived at that time; and the work of reconstruction was immediately commenced. The wreck of the old dam was cleared away, and in 1849 preparations began for the second dam. This dam forms the upstream triangular section of Fig. 1.

I quote as follows from a pamphlet published some years ago:

"In April of that year (1849) two coffer dams were built, one on each side of the river, and each extending 200 feet from the bank into the stream. They were completed in May, the water pumped out and the rock excavated to a depth of 6 feet. The construction of the main dam was then begun by laying down three 15-inch square sticks lengthwise across the river. The dam was

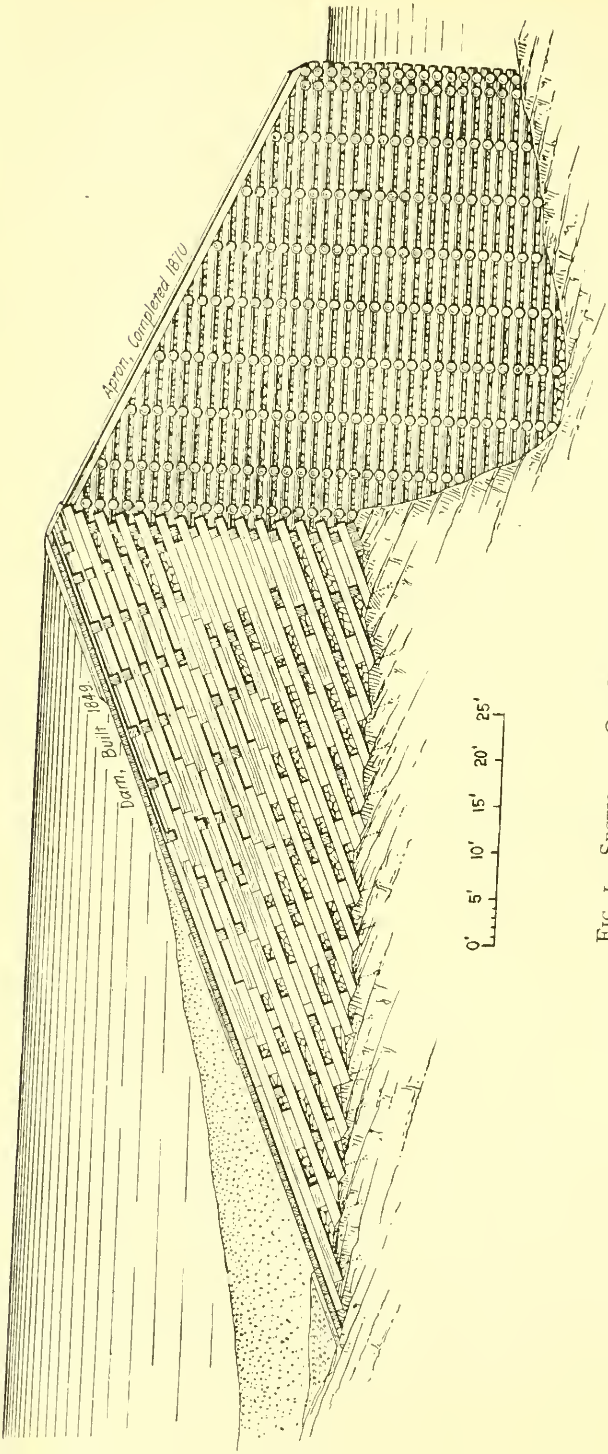

FIG. 1. SECTION OF OLD WOODEN DAM.

Figs. 1–6 are reprinted, by permission, from *Engineering News* of May 13, 1897.

started in sections 6 feet from center to center, and, as the river is 1019 feet wide at that place, there were 170 sections. These sections were connected or tied to each other by 12-inch square sticks running across the river. The structure above the foundation sticks was made up of alternate courses of these ties and rafters, also 12 inches square. Between the rafters, in the same course with the ties, short blocks were introduced to stiffen or prevent the bending of the rafters. At the splicings of the rafter long pieces were put in, treenailed to the rafter with eight 2-inch treenails of oak. The foot of each rafter was scribed and bolted to the rock with 1¼-inch iron bolts. The structure was thus reared to its full height of about 30 feet, and its upstream surface covered with 6-inch plank with the exception of a space 16 feet wide by 18 feet long, which was temporarily left open. The toe of the dam was secured by placing a second covering of plank at right angles with the first, with the lower end scribed and bolted to the rock. Except the space temporarily left open, this structure was filled solid with gravel. Four feet of the crest of the dam on the upstream side was covered with boiler iron ⅜ inch thick, for protection from ice and driftwood.

"In this manner 400 feet of the dam were completed, 200 feet on each side of the river. As the summer advanced another section of 200 feet was added to each side, leaving but 217 feet open for the water to run through. A coffer dam was then built covering this space of 217 feet, and the water of the river allowed to run through the four spaces 16 feet wide left for the purpose in the four previously constructed sections.

"After the completion of the middle section of the dam the last coffer dam was removed, and preparations made to stop the temporary openings through the structure, which was done by gates hinged to the planking. These gates were closed on Monday, October 22, 1849, two alternate gates being first closed by knocking out a prop which held them parallel with the water, and an instant later the other gates were closed in the same manner.

"The flow of water through the temporary openings was stopped at about 12.30 midday, and it was not until ten o'clock at night that the water began flowing over the full length of the dam."

In order to insure the permanency of this dam all the open spaces were filled and closely packed with stone and gravel to a height of 10 feet, and the planking of the upper portion of the dam was doubled to 18 inches of solid timber.

The dam is founded on a ledge of red sandstone and slate, which dips downstream about 30° from a horizontal plane.

The bed of the river was graveled for 70 feet above the dam, and this graveling carried some 30 feet over its sloping surface, which lies at an angle of about 20° from the horizontal, and is 92 feet in width from the foot to the crest of the timber. This dam is said to have cost about $150,000.

The bulkhead at the west end of the dam is 140 feet long between the end of the dam and the shore, and 46 feet wide. In this bulkhead are located the head gates, which are operated from a gate house extending along its top.

This dam has withstood the wear and tear since it was built, and is still standing, in spite of the fact that a new cut-stone dam has been built a short distance below it. It has, however, had some troubles. An examination in 1868, after a very heavy freshet, showed some bad leaks, and it was found that the water falling over the crest of the dam had washed away the ledge underneath and in front of the structure to a depth of 20 to 25 feet (see Fig. 1), and that the eddies caused by the falling water had turned logs and ice back against the structure and had broken away many of the timbers and part of the rock to such an extent as to imperil its permanency.

To check this action, in 1868, 1869 and 1870, another large crib-work structure (see Fig. 1) of greater volume than the original dam was built in front of it, and tied to it as solidly as possible. This structure is of round logs in pockets 6 x 6 feet square, which were filled with stone; and its top was covered with 6-inch planks of hardwood sloping downstream. The slope of this apron being about parallel with the dip of the rock, the erosion of the bed of the stream further down was still carried on, and at the time of starting the new stone dam about 20 feet of the bedrock had been worn away. This new apron cost between $250,000 and $350,000.

With the exception of this apron, but little repairing was required from the time the dam was erected until 1879, when a break in the plank top occurred; and between that year and 1885 there were so many leaks of this nature that 20 feet of the upper surface was replanked; and at the same time a line of sheet piling was driven the whole length of the dam some distance back from the face. This sheet piling was gravel-puddled on both sides, with the idea of making the structure water-tight. All these repairs were accomplished in sections by building a coffer dam about 100 feet long around a section of the main dam.

Since 1885 numerous small leaks have started, and a large amount of gravel seems to have been washed to the river bed below, indicating that the permanent tightness of the structure was threat-

ened. There have been but two large breaks, however; one occurring in 1893, and another a year later. The first was a hole, approximately 4 x 6 feet, about 11 feet vertically below the crest, which was repaired by dropping over it a gate 8 feet square constructed of two layers of 3-inch chestnut plank. The excess of size of this cover was due to the necessity of reaching a solid bearing at two adjacent timbers of the structure, which are 6 feet between centers.

The second hole was not quite so large, being about 4 feet square, and was repaired in the same manner. The leakage gradually increased until in 1895 it amounted to 118 cubic feet per second, or, at a total head of 60 feet, 800 gross horse power.

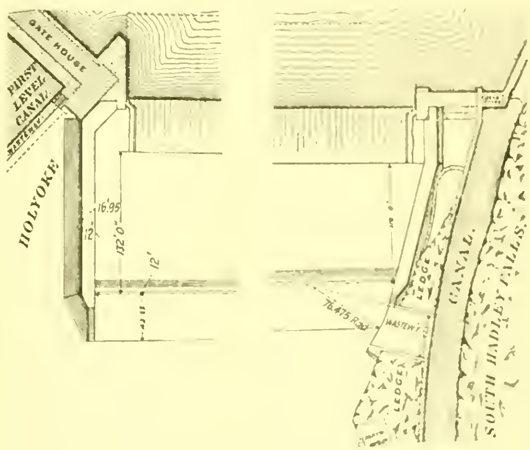

FIG. 2. PLAN OF OLD AND NEW DAMS.

In the year 1891 the Holyoke Water Power Company decided to construct a new stone dam as near the old one as convenient, and of such design as would be as nearly permanent as possible. Surveys were begun that year, and, owing to the erosion of the river bed immediately below the apron of the old dam, the nearest location was found to be 132 feet at the southerly end and 112 feet at the northerly, measured from the toe of the apron to the line of the top of the stone dam. The total length of spillway is 1020 feet between abutments, and the old dam is to be left where it is, the space between the two gradually becoming filled, making a solid dike more than 150 feet wide and nearly as permanent as the surrounding hills. (See Figs. 2, 3, 5 and 6.)

The abutment at the south or Holyoke end (see Fig. 5) starts at the old gate-house bulkhead and runs at right angles with the line of the old dam. Its top extends just beyond the top of the

new dam, whence it is stepped down to the toe of the structure. This abutment is 12 feet thick on top and 28 feet thick at the bottom. The top is 12 feet above the level of the dam, or 42 feet above the bedrock. Like the dam itself, this and the north or Hadley Falls abutment are constructed of heavy rubble masonry, laid in rich Portland cement mortar. On its south side and top, and for 17 feet down from the top on the north or water side, this abutment is faced with cut granite blocks of large dimensions.

Owing to the shape of the ledge, and to a canal location at the north end, the north abutment is skewed at an angle of about 15° with the line of the dam, and between the top and toe of the new dam a wasteway is built over the ledge of rock, the drop face of which curves in with a radius of about 76½ feet, the fall of the wasteway being about half on the lower slope of the dam, the rest falling into the river.

The north abutment, where not built against the ledge, has the same dimensions as the other.

As said before, the dam itself is 1020 feet long at the spillway. It is 30 feet high above bedrock at the back face, and the bottom course on bedrock is 54.22 feet wide from the back line to the tip of the toe on the downstream side. (See Figs. 5 and 6.) The back face is stepped off one foot in five all the way to the top as a batter, the steps affording a footing for the coffer dam. The rear part of the top is beveled for a width of about five feet, beginning at a point 2 feet below the crest and running to a point on top 2 feet back of the center line. There is then a level space 2 feet wide to the center line, and from that point the face of the spillway begins in a parabola, the form of curve being that which would be taken by a body of water 4 feet in depth flowing freely over the crest. This curve extends down the face of the spillway to the point of reversal, where it takes the form of a cycloid or the "curve of quickest descent" to the bottom at a point 34.89 feet from the center line, thence rising to the toe 7.33 feet beyond to a height of 0.98 feet above the bedrock, in order to break the fall of water and to prevent as far as possible the erosive action on the river bed. The face of the spillway has been left rough.

The body of the dam is constructed of heavy rubble masonry laid in rich Portland cement mortar, with beds inclined somewhat from the horizontal, the downstream side being the highest. The spillway, back face and 5 feet of the top are faced with heavy granite blocks, those on the lower part of the spillway being fastened together with galvanized iron dogs, while those on top are secured together with galvanized iron dowels. There are some 34,500 cubic yards of rubble masonry in the entire structure.

The excavation in the bed of the river was done by the company by day work, and took three years, being completed in 1896. The trench for the toe of the dam was excavated to an average

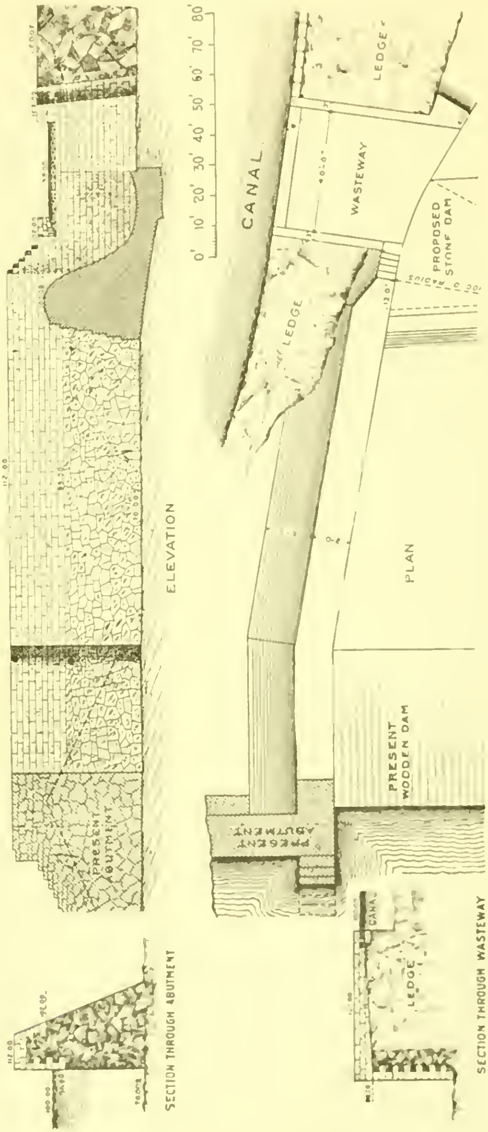

Fig. 3. Details of Dam at South Hadley Falls End.

depth of 8 feet, and from 15 to 18 feet in width, the bottom being leveled off by a bed of concrete for the reception of the masonry. Back of this the rock was roughly stepped to afford a good bearing for the rubble masonry. The bedrock is partly blue slate and partly

red sandstone, and about 13,000 cubic yards were removed. In order to drain this excavation during construction a trench 600 feet long, about 17 feet wide and 10 feet deep was excavated, beginning at a point near the center of the river and running downstream parallel with the flow of water.

Seldom have specifications been so carefully drawn as were those for this work, and the call for copies was so great that some six hundred have been distributed. Doubts were expressed by many engineers and contractors as to the requirements being exactly fulfilled, but, owing to strict interpretation of the specifications and most rigid inspection, the result has been exactly as required, and the work stands to-day a monument to its engineers.

The stone for rubble masonry was taken from the river bed below the dam. The granite is from a quarry at Vinal Haven, Maine, and the cement was furnished by the Alpha Cement Company, of Philadelphia.

The rubble was laid with full joints, while the granite was laid with joints but ¼ inch wide, the mortar being one part cement and two parts sand.

Every piece of granite was laid by instruments for line and grade, and the batter was obtained from templates supplied by the company.

The dam was constructed in four sections, the south end and a center section just north of the drain channel being built up for a considerable height first. Then a coffer dam was built on the first level of the north channel, thus turning the water through the center channel, while a section of dam 5 feet high was constructed behind it. The coffer was then transferred to the center channel, and a section 10 feet high built in that opening. In this way the alternate sections were built in until the structure was complete. The cost of the entire work is said to have been between $600,000 and $700,000.

Up to the time of the development at Niagara the Holyoke water power was the largest in the United States. The drainage area of the Connecticut River above Holyoke is about 8000 square miles, and the average daily flow during 1895 was 11,951 cubic feet per second, or 82,000 gross horse power. The minimum power of the river at Holyoke has been estimated as 30,000 horse power, but is now called 22,000.

The system of distributing canals (Fig. 4) is laid out on the plain inclosed by the bend of the river, and consists of three levels, the fall between the first and second levels being 20 feet; that between the second and third level 12 feet, while the fall from the

third level canal to the river at its average stage is 28 feet. Between the marginal canals and the river the fall varies from 23 to 28 feet, according to locations and the stage of water.

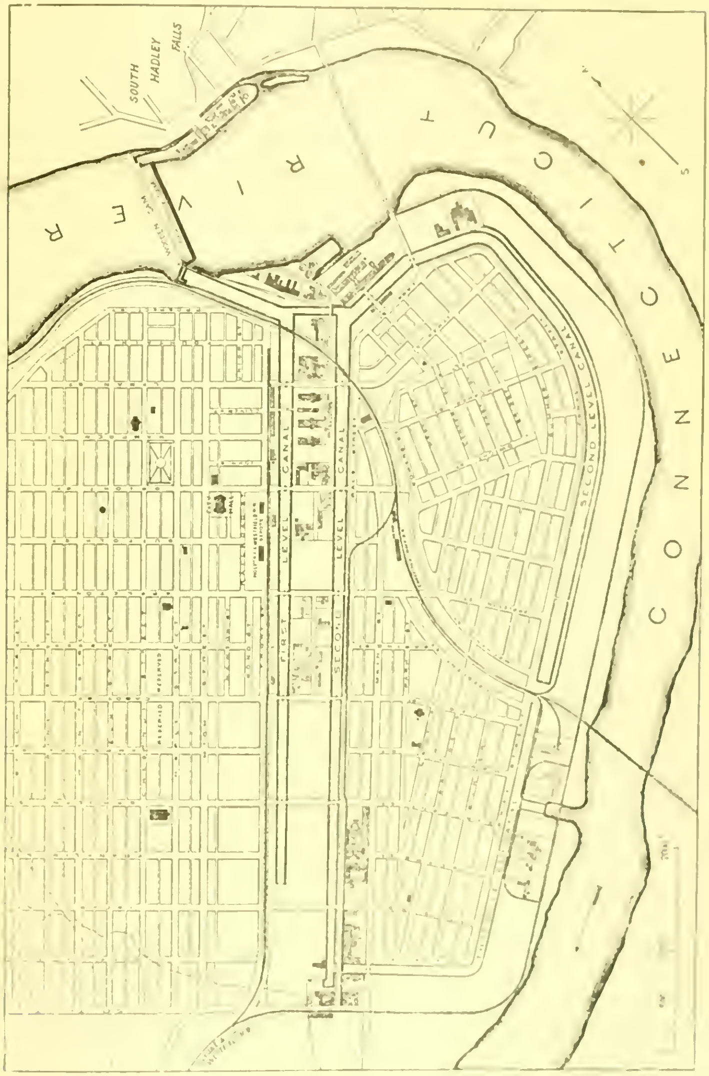

FIG. 4. PARTIAL PLAN OF CITY OF HOLYOKE, SHOWING DAMS AND CANALS.
Shaded Areas are Manufacturing Establishments and Public Buildings.

The head gates in the bulkhead are fourteen in number, twelve of them being 9 feet wide and 15 feet deep, while the remaining two are $4\frac{1}{2}$ feet wide by 11 feet deep. All are operated by gearing actuated by a turbine in the abutment.

A waste weir just below the gate house disposes of surplus water in the canal. Careful watch is kept upon the level of the

water, and more or less is let in through the gates in order to maintain as nearly as possible a constant level, no matter what the quantity used may be.

The main or upper level canal (Fig. 4) extends in a southerly direction for about 1000 feet, then turns at an obtuse angle and runs southwest for about a mile. For the first run of 1000 feet this canal is 140 feet wide, and the water is 22 feet deep. The width decreases from the bend at the rate of one foot in every 100 feet of length.

The second level canal, beginning at a point some distance beyond the extreme end of the first level, runs parallel with it, at a distance of about 400 feet to the northeast, and serves as a raceway for the mills taking water from the upper level. At the east end of this course it turns and runs directly east for a distance of about 800 feet. It then follows the course of the river for about a mile and a quarter at a distance of about 400 feet from it, the margin of land between the canal and the river serving for the location of mills. The second level canal is 140 feet wide for about 2000 feet, but converges to a width of 100 feet at each end. Mills along the south end of this level take water from it and waste into the third level canal, which, starting at a point opposite the south end of the second level, runs southeast for about 1000 feet, then, making a right angle turn, it runs back up the river and parallel with it until it meets the end of the second level. The depth of water averages 15 feet. The third level is 3550 feet long, 100 feet wide and 10 feet deep.

Waste weirs are so located along the canals as to dispose of any surplus water.

The charges for power and the method used for computing it are perhaps the most interesting points about this great enterprise, and it may be well to give some space to the discussion of charges for power generated by water.

The general public has become so accustomed to buying supplies, whether cheese, gas, coal or electricity, by meter, that the fact that water power has been almost invariably sold at a flat rate, based upon a maximum use, which cannot be exceeded, has been overlooked. Speaking of electricity, only recently has the point been fully and plainly brought out that the method of charge by meter is not fair to consumers or to producers, and consequently measures have been taken to remedy this defect. Owing to the fact that the storage of electricity for any great supply is not practicable, a straight meter charge for current does not take into account differences in manner of consuming current as bearing

upon the fixed expense of supplying that current. For instance, a large factory using light for about one hour per day would require the electric plant to be kept ready for its supply. It would, then, have to be large enough for the continuous supply of this maximum demand, although the payment by the factory, under a straight meter charge, may be no greater than that by another customer who consumes the same number of meter units by using his lights for a greater number of hours, and who therefore requires but a small plant for his supply. It is true that the *operating* expense of the electric plant per unit will be practically the same in both cases, but it is readily seen that the *fixed* expense per unit for supplying the large factory must necessarily be greater than that for the other customer. These studies have resulted in a more rational method of charging for electricity, and, after having been in use by some of the municipally owned plants in England for some years, this method is now used by most of the large plants throughout the United States.

The same argument bears on the charges for water power, as nearly all of the expense for such power is fixed, even the labor being practically the same whether the whole or any part of the plant employing the power is in use, and whether loaded fully or in part.

It may be fairly argued that in the past those consumers (such as paper mills and textile manufacturers) who located on rented water powers had occasion to use continuously whatever amount they required, yet nearly all other industries use a varying amount of power, the aggregate of which is always less than the maximum for which they pay. In comparing the cost of steam power with that of water power, it has been very common to compare the *average* amount of *steam* power developed with the *maximum* amount of *water* power paid for, which is manifestly unfair; but on most of the older water powers the rental has been so low for the maximum demand as to leave no chance for comparison with steam by any method. For instance, in Holyoke, since all the power available has been rented, growing industries have had to provide for extensions by erecting steam plants, and, as coal sells at wholesale for about $4.00 per ton, these plants have usually been designed for the greatest economy, and steam power has been produced at a very low rate. Notwithstanding this fact, the water power in use would, under no conditions, be exchanged for the best steam plant that engineers have been able to install.

The marvelous development of electrical transmission of power has changed all the old conditions, and now the power of the water-

fall, developed on the spot, is sent to the point of use over slender wires, rather than through expensive canals, and the room needed for power appliances can now be used for productive purposes.

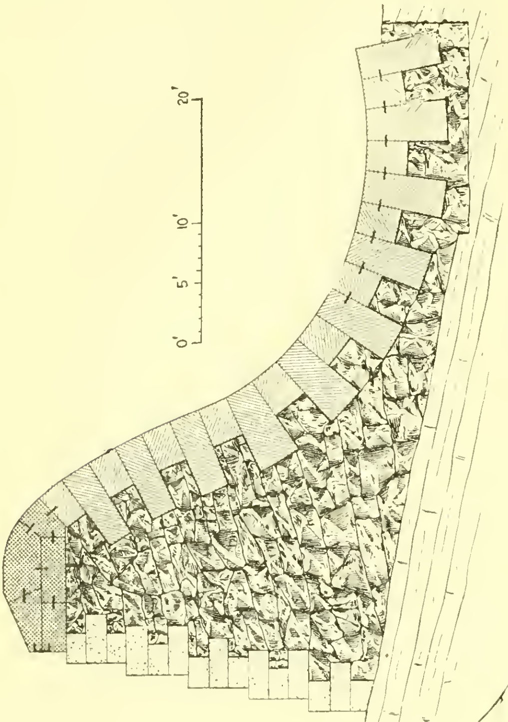

FIG. 6. CROSS SECTION OF DAM.

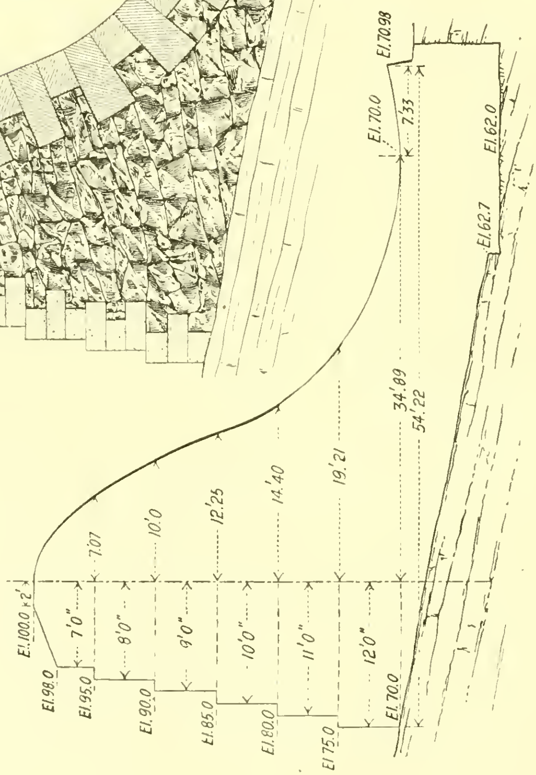

Fig. 5. Outline Section of Dam.

Naturally the question of method and amount of charge becomes more important than ever, and, as the industrial uses to which the power is put are more varied in character and apt to be greater in number and smaller in demand, the rates have to be readjusted to fit

the circumstances. It is obvious that where there are a great number of customers using varied amounts of power at different periods of the day or season, it is possible to make use of the same power plant machinery for supplying a number of such demands, the aggregate of which, if they were continuous, would be much greater than the maximum capacity of the power plant, and it is therefore not necessary, even working close to the theory, to charge each customer with the whole fixed expense for the amount of plant which he may call for at times; but this charge can be divided according to the load factor,—*i.e.*, to the proportion which the average demand bears to the maximum capacity of the plant, or the proportion which the maximum demand made upon it bears to the capacity of the plant. While the variable expenses of the ordinary water power are so small, in comparison with the fixed expense, as to be negligible, and while, therefore, in the case of the more diversified distribution nearly always resulting from electrical transmission, the charge to be made results finally in a flat rate for a stated amount of power, yet it is more practicable to make a certain portion of the charge flat and uniform for the maximum demand, and then make up the remainder on a sliding scale based on the total number of units consumed as shown by the meter.

All these points were carefully studied when rates were made for the Niagara Falls Power Company and its connections, and the result was the card with which you are all doubtless familiar, and which is based upon the theory just advanced.

The grants of the Holyoke Water Power Company to its customers (for they are grants rather than leases) are especially interesting in that they are made perpetual, and are recorded in the registry of deeds at the county seat in the same manner as any other deed.

The grant is made for water power, but every grant carries with it the right to the land necessary for the erection of buildings; and the price is based wholly and only upon the mill powers of water, and not upon the amount of land involved.

The original grants were apparently made with the idea that it would take many generations to use the full capacity of the river. These leases cover what is now called *permanent* power, and the consideration for this was originally a lump sum, sometimes called a bonus, of $5000 per mill power and an annual rental of $450 per mill power forever. Each of these leases carried with it the right to draw 50 per cent. more water than was specified, and for this a charge is made of $2.50 per mill power per day and $2.50 per night, being substantially $1500 per annum per mill power;

and at the present time every owner of a permanent mill power uses his full surplus privilege.

I quote as follows from the proposal issued by the power company to its customers such articles as refer to the rental of the power:

"Article II. Each mill power at the respective falls is declared to be the right, during sixteen hours in a day, to draw from the nearest canal or water course of the grantors, and through the land to be granted, 38 cubic feet of water per second at the upper fall when the head and fall there is 20 feet, or a quantity inversely

FIG. 7. HOLYOKE DAM, APRIL 20, 1900. WATER 9 FEET 7 INCHES DEEP ON CREST OF DAM.

proportionate to the height at the other falls. And in order to prevent disputes as to the power of each mill privilege in the variations of the height of the water from changes of the seasons or other causes, it is understood and declared that the quantity of water shall be increased in proportion to the reduction of the height, one foot being allowed and deducted from the height of the actual head and fall, and also from that with which it is compared before computing the proportion between them. Thus on a head and fall of 32 feet the quantity of water to be used would be 23 9-31 cubic feet per second, and the respective parties, where either has any lawful interest therein, may at all reasonable times, in a peaceable manner, and after due notice to the principal steward or agent then

on duty at any mill, enter the raceway thereof to measure and compare the quantity of water with the quantity granted; and in the measurement all wastage shall be included. And may also adopt and use such other mode of making or verifying the said measurements as the circumstances of each particular case may require."

After going on to say, in other articles, that the grantors must forever keep in good repair, etc., the canals, and must forever maintain a dam across the Connecticut River, and that the grantees shall maintain in good repair the flumes and raceways, Article V reads:

"In order to continue in the grantors an interest in common with the grantees for the preservation and support of the mill powers which may be granted, and to secure a fund to indemnify the grantees for expenses which may be incurred by them for making repairs if the grantors should improperly neglect to make them, it is proposed that part of the consideration of every sale, and all that is to be allowed the grantors for the repairs, etc., by them assumed, should be paid or secured to them in the form of a reservation of rent. *It is therefore declared* that each mill power, with the land to which it is annexed, shall forever be subject to a perpetual annual rent of at least 260 ounces, troy weight, of silver of the present (1859) standard fineness of the silver coin of the United States, or an equivalent in gold, at the option of the grantee at the time of payment; which rent is to be paid in yearly payments forever, free from all charges or deductions whatever for taxes or assessments of every description which may be assessed or levied upon any granted premises after the making of the deed, all of which are assumed by the grantees. And a perpetual annual rent, at last equal to the above, shall be reserved for every mill power hereafter sold."

After the full power of the river at its lowest stages was sold to consumers there remained, during the greater part of the year, a vast surplus of water, which it was, of course, policy to use, and the power company instituted what it designates as non-permanent leases, or power which is not guaranteed, but will be supplied when there is more than a sufficient quantity of water in the river to supply all the permanent power, together with its 50 per cent. surplus. The rate of charge for non-permanent power is a bonus of $4500 per mill power and an annual rental of $1500 per mill power, with a pro rata rebate on the rental for such time as the water may be too low to use.

At times of low water the power is not so divided between the consumers of non-permanent power that they may have a constant supply in proportionally reduced amount, but each in turn receives the full leased power for a proportionately reduced time. The result has been that the average rebate in time has not much exceeded twenty days per annum, and during many years has been as low as six or eight days.

Permanent power is practically guaranteed forever, except in case of accident obviously not the fault of the grantors, in which case proportional rebate is made for the time during which the power is not ready for use. Should the power be stopped owing to carelessness of the grantors, then the customer would be entitled not only to rebate, but also to suit against the grantors for damages.

In closing, let us briefly review the effect which the development of this great water power has had upon the community immediately interested.

Starting with the construction of the dam, there were fourteen houses and three small mills located upon the site of what is now the great industrial city of Holyoke. The village was incorporated as a town in 1850, and as a city in 1873. In the year 1865, sixteen years after the establishment of the dam, the population numbered 5648, and the total valuation was $3,130,342, of which the greater part must have been the property of the water power company. In 1898, thirty-three years after, the population had increased to 44,982, an increase of 696 per cent., and the valuation to $36,424,-460, an increase of 1064 per cent. Few booms in the new West exceed the increase here shown, and scarcely one could equal it in the solidity of its established industries.

Going back over the history of this corporation, the record of its results, the growth of the city in population and wealth, all of which practically owes its existence to the establishment of the dam, it is perhaps not surprising that there are so many water power projects being brought to the attention of investors at the present time.

HIGH-WATER PROTECTION METHODS ON LOWER MISSISSIPPI RIVER.

By William Joseph Hardee, Member American Society Civil Engineers; Member Louisiana Engineering Society.

[Read before the Louisiana Engineering Society at adjourned regular meeting, June 18, 1900.*]

The preservation of the levee line on the lower Mississippi River during periods of high water is a most important subject and is worthy of much thought and attention to avoid the numerous and costly mistakes which have been made in the past. When the method under which that character of work was done during past years is considered, it is most surprising that so much success was achieved and that the mistakes which were made did not prove more extensive both as to cost and disaster.

Up to the present time there has been no well-defined organization for the systematic conduct of high-water protection work. The nearest approach to anything like systematic, intelligent and harmonious co-operation on the part of those engaged in such work was during the flood of 1897; but this was far from satisfactory and is susceptible of great improvement.

The absence of anything like system will be readily appreciated when it is remembered that there are engaged in the work some six practically independent agencies—the district levee board, the Parish officials, the State officials, the United States officials, the railroad officials and the individual planter. At the present time not one of those agencies has the available resources with which, alone and unassisted, to care for the levee line during an extraordinary flood.

The local district levee boards are charged by law with the responsibility of preserving at all times the integrity of their respective levee lines; and, except in a few instances, this charge has been intelligently executed; but there have been occasions when the task has vastly exceeded the resources of the several boards.

If those boards had possessed ample means, they would to-day have the levee line of their respective districts in condition to resist successfully the biggest flood so far experienced without the necessity for an amount of work in excess of their means. But they have not possessed adequate means to accomplish this end, and it is a fact that while the levees have been steadily improved, the

*Manuscript received June 25, 1900.—Secretary, Ass'n of Eng. Socs.

floods of the past have found them in an imperfect condition, and a great amount of work of an emergency character, has been necessary to successfully preserve them during high-water periods. On such occasions the other agencies have been requested to assist, or they have voluntarily proffered assistance by reason of their indirect connection with the cause and their general interest in the work.

It is a strange fact that each of the other five agencies, when rendering assistance, seemed to claim superior wisdom, and usually insisted, not infrequently to the disadvantage of the work, on proceeding according to its individual judgment. Confusion was the inevitable result, and from confusion sprung wastefulness and insubstantial work, sometimes accompanied by disaster.

Confusion, attended by wastefulness and insubstantial work, has oftentimes been due to a lack of forethought or proper advance consideration. In some instances expensive arrangements were made, and large quantities of perishable materials were provided for prospective high-water protection work which never materialized. On other occasions the magnitude of a flood was neither anticipated nor appreciated until, figuratively speaking, the last minute, and then the necessary work had to be done hurriedly and frequently under the adverse conditions of bad weather, resulting in increased cost and less stability.

Based on his observations and experience, the writer believes that, with the resources at command, a system for economically and efficiently preserving the levee line during flood periods can be devised.

It is not considered advisable, however, to advocate a system which would involve the combined resources and efforts of the entire six agencies referred to, because, depending on time and circumstances, the resources of those agencies vary. A more practical system would be such a one as would involve one agency only, with adequate means prosecuting it, and then, as occasion would demand, the necessary work may in advance be divided and certain functions allotted to the different agencies according to the practicability of applying the resources of each.

The old maxim, "In time of peace prepare for war," applies with equal force to the preservation of levees. If it were practicable to do so, the levee line should, during low-water period, be put in such a condition that the usual cases of emergency which now arise would be in great part, if not altogether, removed. It is hoped that, with advancing years and the continued expenditure of large sums of money, this happy condition will be realized at no very distant date.

But, taking the levee line as it stands to-day, there are certain kinds of high-water protection work, as will be more fully described later on, incidental to every flood in excess of a stage which puts 3 feet or more of water against a levee. The full extent of protection work is, of course, governed by the size and duration of the flood. If it were possible to anticipate the approximate size of a flood, a large amount of work could be more substantially done and at a minimum cost. As a matter of fact, a flood in the lower Mississippi River can be anticipated within reasonable limits, and far enough in advance of its realization to permit the deliberate execution of a large amount of preliminary protection work.

An approximate relationship exists between adjacent water gages on the Mississippi River when the flood surface of that stream is not disturbed by crevasses or augmented by the waters from tributary streams. For instance, a certain maximum at Cairo will produce a certain maximum at Memphis, the next prominent gage station below. A gage, however, below a tributary stream, may be affected by a flood poured out of the tributary, but, as there is an approximate relationship between a gage so affected and the next gage below, comparisons may be successively carried on until the place is reached at which a forecast is desired. The great bulk of the water which produces a flood in the lower Mississippi River is derived from the Ohio River and the Mississippi River itself above Cairo. A flood out of any of the tributary streams—St. Francis, White, Arkansas, Yazoo or Red—does not materially add to the height of a flood in the Mississippi. The effect of a flood from any one of those streams is rather to prolong the passage of a coincident flood in the Mississippi than to increase its height. Of course, floods poured simultaneously out of all those streams or out of each stream at or about the time that the crest of a coincident flood wave in the Mississippi passed its mouth would materially increase the height of the flood in the latter stream. But the records since and including 1890 do not show that such a coincidence of floods has occurred. They show, however, that some only of the tributaries contributed more or less to the height and duration of the floods of 1890, 1892, 1893 and 1897. On the other hand, the Mississippi River may be abnormally depressed below the mouth of Red River, as has sometimes occurred, on account of Red River being low and a large volume of Mississippi River water in consequence thereof being drawn off by the Atchafalaya River.

As the great floods emanate north of Cairo, that place can properly be considered the strategic point, and the Cairo gage can be accepted as a fairly reliable index to what will follow on the

lower Mississippi. A wave, such as we are concerned with, in so far as it bears on the subject-matter of this paper, occupies from ten to fourteen days in passing from Cairo to Vicksburg, so that we always have that much advance notice of what is coming. The tributaries, of course, should be closely observed, and proper allowance should be made for any influence they might exert.

It is the writer's opinion that no damage can befall any of the existing levees when there is less than 3 feet of water against them. But at about the 3-foot stage the pressure is sufficiently great to commence developing weaknesses due to faulty construction, unequal shrinking or leaks caused by burrowing animals. It, therefore, follows that unless a flood in excess of that 3-foot stage is experienced, there is no need for protection work of any kind; but, as soon as it is evident that the 3-foot or higher stage will be experienced, preparations for a high-water campaign should be immediately begun, and conducted as the conditions attending the expansion of the flood demand.

The battures or foreshores vary in elevation with respect to the high-water surface at different places along the river. The ground is usually higher near the edge of the bank than it is at the levee, so that a flood which covers the ground near the edge of the bank puts several feet of water against the levee. The water usually finds its way to a levee through depressions and drainage ditches, and, with few exceptions, is well against the levee before the entire foreshore is fully overtopped.

The following is the approximate height which will put 3 feet of water against a considerable length of the levee line in the vicinity of the respective gages, though a foot or so less in height will put 3 feet of water against short lengths of levee: Vicksburg, 42 feet; St. Joseph, 38 feet; Natchez, 44 feet; Red River Landing, 42 feet; Bayou Sara, 37 feet; Baton Rouge, 34 feet; Plaquemine, 29 feet; Donaldsonville, 26 feet; College Point, 23 feet; Carrollton, 12 feet. The gage at Fort Jackson is not included, as its elevation is so often influenced by wind and tide.

It is now in order to ascertain what height at Cairo culminates in 42 feet at Vicksburg and 42 feet at Red River Landing.

A comparison of fifteen gage observations selected at random shows that for stages of 25 feet or less at Cairo the time consumed in the passage of the crest of a wave from Cairo to Vicksburg varies from four to eight days. But as we are interested only in stages which culminate in 42 feet at Vicksburg, a comparison of lower stages should be disregarded.

On account of the closure of St. Francis basin during recent

years, flood waves which occurred prior to 1898, and which were in excess of bank full stage, should be disregarded, as they would prove misleading. A comparison of all the flood waves of consistent elevation, since and including the year 1894, shows that 42.7 feet at Cairo will culminate in 42 feet at Vicksburg, and that the time of passage varies from ten to fourteen days, a fair average being twelve days. These figures include an addition of height and prolonged time of passage due to augmentation by water from the St. Francis and White Rivers, which is almost invariably coincident with a flood of the elevation we are discussing in the Mississippi River.

Storms which occur in the Valley of the Ohio River usually originate west of there, and, in their passage, traverse the territory drained by the St. Francis and White Rivers.

The probable maximum height which the gage at Cairo will reach may be estimated with fair accuracy by considering the gages at stations north of that place on the Ohio and Mississippi Rivers and their tributaries, so that by a series of deductions it is possible to secure more than twelve days' notice of what is to be expected, as well as to forecast beyond the 42-foot stage at Vicksburg.

The records show that at the time of the year when the gage at Vicksburg reaches 42 feet Red River and its tributaries are usually low, from which it may be safely inferred that 42 feet at Vicksburg cannot be expected to culminate in more than 39 feet at Red River Landing; the time of passage may be placed at two days though on an average it is a fraction less.

It must, therefore, be noted that high-water protection work of some kind will be necessary under the proposed system between Vicksburg and Bougere (lower terminal of the levee system of the lower Tensas district), before work of any kind will be necessary below Red River Landing.

Ordinarily,—*i.e.,* when the Red River and its tributaries are low, as is usually the case,—the gage at Vicksburg must read 46 feet to produce 42 feet at Red River Landing.

Failure of levees usually results from one of the following seven causes:

1. Insufficient height, which permits the water to flow over the top of the levee, cutting it away.

2. Leakage due to faulty construction; to uneven shrinking or sinking, or to the operations of burrowing animals resulting in the formation of cracks or holes, which, under some conditions, rapidly enlarge as the water flows through them.

3. Sloughing, due principally to some defect in the body of

the levee, which permits the water to percolate too freely through it, and which, being attended by defective drainage on the land side, results in the land slope becoming saturated and so softened that it will not stand.

4. Sinking, the result of the levee having been built on an unstable foundation, generally of a quicksand character, which, under the influence of excessive wetting and the pressure exerted by the weight of the embankment, is displaced and causes the embankment to subside into the cavity thus created.

5. Wave-wash, which, when the river is made rough by wind or by passing steamers, attacks the surface of the levee not protected by a close growth of grass.

6. Excessive erosion at salient angles due to removal of all of the old levee, causing abnormal velocity of the current, which washes and cuts away the controlling embankment.

7. Cutting due to operations of malicious or insane persons.

INSUFFICIENT HEIGHT.

Earthen embankments, no matter how well protected by a growth of sod, will be destroyed by water flowing over their tops for any considerable length of time. It is therefore, absolutely necessary, to keep the top of the levee well above the water surface. To assure this, the levee line should, if practicable, be maintained at a uniform grade, even if the cross-section of the embankment cannot at the same time be given the standard dimensions of 8 feet crown and 6 feet of base to each foot of height. All of the low lengths of the levee line should be brought to the standard grade well in advance of high water. The work can be done then not only at much less cost, but so much more substantially, and the cost of protecting the new work with washboards will be saved. This matter was seriously considered just after the flood of 1897, but, owing to the long length of low levee line, and the limited amount of money available for levee improvement, nothing much was done beyond a length of about five continuous miles by the United States in the Lower Tensas District and a few miles by the Atchafalaya Board scattered throughout its district.

The length of low levee has since then been greatly reduced; it is believed that it is now practicable to raise all of the remaining lengths of low levee to standard grade during the coming construction season. But if this is not done before a flood is in sight which will overtop the low lengths of levee, as soon as a conclusion as to the probable height is reached, which should be as far in advance as possible, the topping or "capping," as it is commonly

designated, should be put on with teams and scrapers. Work done in this manner generally costs less and has the advantage of greater compaction and is in consequence much more substantial than earth placed by handbarrows or wheelbarrows. To postpone the capping until the water is near, or actually on, the crown of the levee, or until the land in the rear becomes submerged by seepage or rainwater due to defective drainage, is taking an unjustifiable risk, and entails an avoidable increase in the cost of the work.

Whether the capping be put on by teams or by other means, it should be protected with washboards against erosion by the waves. In the past capping has been protected by sacks filled with earth or cotton-bale bagging carefully placed along the front surface of the capping. This method should be abandoned; it is more costly and less substantial than wooden washboards. If the capping is put on by teams, the washboards can be most advantageously placed after the earth is in place; but if the capping is put on with wheelbarrows or handbarrows, the washboards should be put on in advance of the earth.

The washboards should consist of 1 x 12-inch x 12-foot lumber, placed parallel to the levee, standing on the 1-inch side and about one foot from the river edge of the crown. The washboards should be held in position by two lines of 2 x 2-inch pickets sharpened and vertically driven at least 15 inches in the levee; two pickets should be driven for every six lineal feet of washboards, one on each side of the boards and with just space enough between to permit the comfortable adjustment of the boards. Each board should be nailed at top and bottom to each picket. The writer has personally directed the placing of many miles of washboards, and has seen much of that kind of work done by others. Sometimes on account of scarcity of materials, or in an endeavor to economize on cost, single pickets only were placed, or double pickets at the junction of boards only, with a single picket at the half-way point between, and the boards were sparsely nailed or the nailing was altogether omitted. These latter methods are falsely economical and should not be practiced. The greater security obtained by the use of double pickets and full nailing will amply compensate for the cost of the additional materials.

Weakness in some of the capping which has been placed in the past has resulted from inattention to small details. In the first place, the portion of the crown of the levee to be occupied by the capping should be thoroughly broken up so as to make a good bond with the new earth. Without such bond there will be free leakage across the line of junction, particularly in the case of thickly sod-

grown embankments. Care must be taken to see that each bottom board touches the levee throughout its length and that it is well pressed into the levee to prevent any under wash; the washboards should otherwise be firmly and securely set, for they are often and for long periods subjected to heavy strains by the waves beating against them, and if not made secure they will work loose. As soon as they get loose and are weakened by the waves they cause the earth behind them to loosen and crumble and wash under the bottom boards, and soon the entire capping is destroyed. Care should be taken to tamp the earth in light layers as it is placed against the washboards, to insure a close union of the two. Otherwise rainwater and over wave-wash water will percolate through the soft earth, impair the union and ultimately weaken, if not wholly destroy, the capping. The top of the capping should be sloped towards the rear from where it joins the washboards, so that both rainwater and over wave-wash will promptly run off.

LEAKAGE.

Leakage is due to either faulty construction, unequal shrinking or sinking, or burrowing animals, and constitutes one of the most perplexing problems a levee engineer has to deal with during high water. Leaks are more or less treacherous, and are both difficult and expensive to stop.

Failure to properly clean and then break up with a plow, or otherwise, the surface of the ground to be occupied by the base of the levee, to insure a perfect bond between the embankment soil and the natural soil; or failure before construction commences to remove all foreign substances which might in after years decay and leave a cavity; or the introduction of foreign substances into the embankment at the time of its construction, may result in leaks.

In some instances, where old levees have been razed in building new levees or where they have caved into the river, the writer has observed in the body of the embankment, large cavities, which could have been produced only by the rotting of a wooden barrel or wooden box or a pile of logs. He has also observed a clear line of demarcation between the embankment soil and the natural soil, indicated by a stratum, two inches or more thick, of partially decayed leaves and trash. This stratum must, by reason of its composition, be permeable, in which case leakage would be free, and, after the trash and leaves would be deposed, the soil of the embankment or the soil of the ground would be attacked and eroded in proportion to the strength of the flow of water through the channel thus created.

There need be but little apprehension in the future from leaks originating in the several manners described. During the past ten years a large percentage of the levee line of the Fourth Engineer District, Improving Mississippi River, has been built anew, and the remaining lengths have been so substantially enlarged as to almost entirely eliminate original defects; the system of inspection has been rigid, and it is not probable that the embankments contain any defects of construction.

Unequal shrinkage cannot easily be provided against. It usually manifests itself in cracks extending in almost every conceivable direction, and its occurrence is most frequent in embankments built of buckshot or clayey materials or in embankments built of those materials and sand, alternately placed in thick bodies or layers. The degree of inequality of the shrinkage seems to be governed entirely by the amount of moisture in the soil when it is put into place.

The earth near the bottom, sides and top of a crack, usually expands when moistened. If it is wetted by slow degrees the crack will usually close up. The greatest danger attending a crack occurs when the soil surrounding it remains unwetted for several years during which time the crack increases in size, and, if a large volume of water be suddenly thrust upon it, the soil will rapidly wash and the crack increase in size until it finally causes the embankment to collapse. Unequal shrinking is rare in embankments built wholly of loam or sand.

The levees should be carefully inspected just before or soon after the water has gotten against them, and, if cracks are found they should be filled and rammed with loose earth, particularly and most carefully on the intake side. If a crack is not discovered until the water is well against the embankment, the exposed portion should be treated as above, and clods, mixed with loose earth, should be dumped into the water over the crack until the flow of water has been entirely cut off.

Lateral cracks in a levee are sometimes caused by the sinking of a section of embankment built on a bad foundation, while the adjoining section, built on a good foundation, stands firm. Such cracks are usually large and conspicuous, and should be .epaired during low water. If not repaired then, they should be treated exactly as has been described for cracks produced by unequal shrinkage.

The attention which has been devoted to draining old burrow pits, neighboring sloughs, etc., has resulted in a large reduction of the nocuous operations of burrowing animals, by destroying their

harbor and breeding places, causing them to migrate to localities more favorable to their pursuits. But the evil still exists to a troublesome degree. Burrowing animals do not work with great success in sandy soils because the walls cave in behind them; it is in clay that they do their best work. For that reason we find few levees built of sandy soils cut up with leaks made by burrowing animals. This kind of leak is mostly found in buckshot or clay levees; a compensating advantage exists in the fact that such soil does not easily erode and a single hole is not always dangerous. If it is no larger than two inches in diameter it will do no damage as long as its size does not increase. It should be carefully watched, and, as long as the water it discharges is clear or free of sediment, all is well. But if it discharges muddy water or a considerable quantity of sediment, such action is plain evidence that the hole is either a very direct one or that it is enlarging by erosion, or that an animal or animals are somewhere at work in it. It has then become a menace to the safety of the levee and should be promptly treated.

The greatest danger to be apprehended from holes through any kind of a levee is the presence of a large number of them within a small area. As the holes enlarge, the intervening volume of earth is correspondingly reduced; individual enlargement results in several holes working into each other and becoming one hole, and this process of conversion, if not checked, may continue until numerous small holes have become one large hole beyond control.

Plugging a hole is rather a simple matter if the intake end of the hole can be located, but to stop a good-sized leak at the discharge end is tedious, expensive and uncertain. The intake end of a hole which discharges out of the land slope of the levee or at the base of the levee, or just beyond the base of a levee, may be several hundred feet distant from a point immediately abreast of it on the river side, or, if approximately abreast of it, a hundred feet or more distant from the base of the levee. There being a well-defined channel affording a line of least resistance, the water flows along that line. But as soon as the discharge end is obstructed another line of least resistance develops, probably a minute channel connected with the main channel, which, under the increased pressure, rapidly enlarges and the water bursts out elsewhere. The flow continues as before, not infrequently to a greater extent if the flow line has been made more direct.

The writer has determined the location of the intake end of a hole by the use of unslacked lime. This method is very tedious, and is not practicable if a large area must be investigated. If un-

slacked lime be dropped into the water just over the intake and is sucked into the hole, that fact will very shortly be manifested by the water discharged by the hole. In order not to confuse the location of the intake, small areas of ground only can be covered at a time.

The use of lime is valuable in some instances, and is recommended to determine if the hole be direct; that is, if its intake end is immediately abreast of the discharge end and within reasonable working distance from the base of the levee. The position of the intake end of a hole largely governs the method which should be employed to stop the leak. In the majority of cases the intake end of a single hole is so far removed from the discharge end that it is impossible to locate it. When numerous holes exist within a small space the intakes are nearly always just abreast of the discharge ends.

It is not considered possible to define a method for universal application in stopping leaks. Nearly all leaks have to be cared for according to their individual characters, and this can come to him in charge only by long experience. The experienced physician does not always need a thermometer and pulse test to determine that a patient has fever; something almost intangible, in the appearance of the patient, the odor of the room and other things, make the fact apparent to him. So it generally is with the experienced levee engineer; he seems to know intuitively whether a hole is dangerous, as well as how it should be cared for. However, some general rules apply to the stoppage of leaks, particularly to the avoidance of expensive and worthless work, which may augment rather than reduce the danger.

A common method for stopping leaks, when the tools and materials are available, is to drive with a dolly, or light hand pile driver, a single line of sheet piling (2 x 12-inch boards tongued and grooved or otherwise prepared to make close joint) into the river slope of the levee or into the ground just at or immediately beyond the base of the levee to a sufficient depth to encounter the hole or holes, and thus cut off the flow of water. This is a certain and comparatively inexpensive remedy if the holes can be encountered, but if the holes are not covered the work is worthless and its cost will have been wasted. Sheet piling should therefore not be employed when the river side position of the hole cannot be definitely located.

As dollies have not been extensively used along the river, a brief description of them is pertinent. A dolly is a stick of square or rectangular shaped timber of varying size and length, according

to the driving power desired, near to the outer end of which, at proper working distances apart, are nailed cross-strips or handboards to furnish convenient grasp for raising it. The inner end rests on the ground or a platform, and is held in position by several stakes or pegs driven about it, the ground end being but slightly lower than the outer end to maintain the dolly on something like a horizontal plane. Enough men are put at the handboards to readily raise the outer end of the stick several feet above the object to be driven. The stick is raised and sharply let fall alternately until the object is driven to the desired depth. Great care should be observed in selecting the position for the sheet piling with reference to the location of the leak or leaks and the character of the soil composing the embankment. The very least possible penetration by the sheet piling is desirable, to reduce vibration and avoid weakening the embankment by cracking or loosening it. In dealing with soils which easily crack or loosen when penetrated, the sheet piling should never be driven into the body of the embankment. Sheet piling should also be driven in the shortest possible time.

During the flood of 1892 a crevasse was caused by inexperienced men driving sheet piling into the embankment at Tessier's Plantation, Pontchartrain District. There were three 3-inch holes in the levee at that place, discharging within a few feet of each other at the land base of the levee. These holes had existed for some years, and had been frequently observed. In those days many such leaks existed at numerous places in that levee district; a few only of them were considered to seriously menace the safety of the levee, and those few were cut out when the river was low. But the great majority were allowed to remain undisturbed. Just before the flood reached its maximum stage, some of the leaks which had been allowed to continue showed serious symptoms, and the Levee Board decided to stop all of them. In this task a number of the bridge gangs of the Yazoo and Mississippi Valley Railroad were employed. A small gang of men, without experienced direction, commenced work during the afternoon driving sheet piling into the river slope of the embankment at Tessier. Mr. J. W. Ross, a nearby resident and ex-member of the levee board, has since told me that he was present during a part of the afternoon the sheet piling was being driven; that before any of the piling was driven the holes were discharging clear water, free of sediment, and that the holes gave no evidence that enlargement was in progress; but that after a few planks had been driven the holes commenced to discharge muddy water and large quantities of sediment. There was no relief gang, and work was discontinued at nightfall, at which time

some six or eight pieces of plank had been driven. At about nine o'clock that night the levee collapsed, and the river poured through the opening. There is scarcely a doubt that the piling cracked and loosened the earth in the embankment, causing it to erode rapidly, and that the sheet piling was the direct cause of the failure of the levee.

Another, but more costly method for stopping leaks having their intake ends on the front slope of the levee or within reasonable working distance of the base of the levee, is to drive vertically two lines of 1 x 12-inch boards, not necessarily arranged to make close joints, from 3 to 6 feet apart, (distance regulated by height of structure) with just enough penetration to furnish good toe hold, sufficiently braced longitudinally and laterally to afford required rigidity. This structure is built in a continuous length from the levee to a point beyond the intakes and back to the levee, and, after the woodwork has been completed, the interior formed by the two lines of plank is filled with earth. The structure is commonly called a mud-box. Sometimes, owing to scarcity of materials or to inexperience of those doing the work, a single line of 1-inch plank was driven, and the entire space between it and the levee was filled with loose earth or sacks filled with earth. This form of structure is called a bulkhead. It is manifest that either bulkheads or mud-boxes, like sheet piling, are worthless unless the sore itself—the intake end of the hole—is reached and covered. The writer has seen a large amount of all three of the kinds of work described which failed to accomplish any good.

Of the three methods named, sheet piling, when practicable, is recommended. It is equally effective, less expensive and most quickly put in place.

When a hole develops serious symptoms and its intake end cannot be located, it must be treated in the most substantial manner possible at the discharge end.

During the flood of 1890 the writer experimented with light sheet iron cylinders of different lengths, having a diameter varying from 10 to 18 inches; they were equipped with soldered handles at intervals to afford good hand hold. To reinforce the cylinders at the base about ten cubic yards of earth was piled in conical shape about the hole, a small drain being left temporarily to take off the water flowing through the hole in the levee. As soon as the earth was in place the iron cylinder was clapped over the hole and forced into the ground by the weight of as many men as could get hand hold. The surrounding earth was simultaneously tamped about the cylinder. Not more than two out of a dozen of the cylinders

proved successful; none of the large ones, over large holes, were successful. The water at first rose rapidly in the cylinders, but gradually diminished in rate until it stopped rising altogether. Generally the water found a line of less resistance, and broke out through the ground only a few feet away.

The common method of treating a leak at its discharge end is by building what is locally termed a "horseshoe," which is nothing more than a mud-box, such as has been already described, built on the land side of the levee, and of such length as may be necessary to leave a good margin of ground on all sides of the leak. While it is expensive, this method is certain in its results if the levee is not too largely infested with leaks, and is recommended in cases of serious leaks when the intake end cannot be definitely located. In the past, when lumber was not available and sacks were at hand, "horseshoes" were constructed by pyramiding sacks filled with earth. Such a structure is unnecessarily expensive, and should be discountenanced.

During some of the past floods the writer has known short lengths of levee to be so infested with leaks that application of all the several remedial measures, which have been mentioned, did not assure the safety of the levee. In such cases collapse was anticipated, and, to provide against disaster, several lines of cribs (the number of lines being regulated by the depth of the water in which the structure was placed) were built and filled with sacks filled with earth. In other words, the crevasse was closed before it occurred. The cribs were so placed as to extend well beyond the base of the levee and at both ends to join sound embankment.

These very bad places were the result of neglect; of failure, when the river was low, to cut out leaks which were known to exist but which were allowed year by year to extend and enlarge until the levee became thoroughly rotten and scarcely more water-tight than a sieve.

The improved condition of the levee line and the attention which is now usually devoted annually to repairs and maintenance warrant the belief that such extreme cases of bad levee, as have just been described, are things of the past.

The treatment of leaks should in the future be more simple and at the same time, less expensive than in the past. To-day much more is known of their character and how to deal with them; and the best remedy only of the past should be applied until some more successful remedy is evolved. It is contemplated, of course, that none but experienced men will direct the work, and that suitable materials with which to do the work properly and economically will at all times be at hand.

The foregoing remarks refer to leaks of an ordinary character, but as very extraordinary leaks sometimes occur, it is thought advisable to describe one that came within the writer's experience and how it was treated, as under similar circumstances the same treatment would seem to be best and should be applied. The following is quoted from my report of the 1897 flood:

"During the morning of April 27, when the water was at 52 on the Vicksburg gage, a large leak developed under the Clagget levee (644-R). At this place both the levee and surrounding soil are light loam. In the rear of the levee within 30 feet of its base there is an old burrow pit about 8 feet deep with almost vertical side next to the levee. Without previous warning a 6-inch stream of water spurted out of the wall of the pit midway its height; it did not merely run out and trickle down, but shot out as if ejected from a hose. Its force was so great as to churn the water into foam in the pit into which it was discharged. There are many theories as to the origin of this leak, but its cause will never be known unless the embankment should be cut and the hole traced."

"It is more than likely a series of disconnected holes or small cavities existing under the levee, due either to burrowing animals or decayed vegetation, or probably both, and under the pressure of water there was leakage from one to another, attended with a certain amount of wash which continued until the several holes were connected and made a free passage for the water through one large channel where the water burst out as described."

"A large force was immediately summoned, and a semicircular wall of sacks built about 6 feet high around the discharge end. The interior space rapidly filled, and the sacks were soon overtopped. In the meantime a large force of teams was put to work, and a run around commenced about 100 feet in rear of the main levee and designed to be about 250 feet long when completed. An opening was left in it as an outlet for the overflow until the new embankment was thought sufficiently high with proper cross-section to hold the filled basin, then the opening was closed. The basin filled rapidly at first, then more slowly; at the end of two days it was found that the basin was still filling, and would overtop the run around. The teams resumed work, and the embankment was raised 3 feet. The basin continued to fill, but as the river commenced falling in a few days, further raising was not necessary. It now stands with an 8-foot crown, about 2 to 1 inch side slopes, and a grade about 3 feet lower than the highest point reached by the river."

SLOUGHING.

When water has stood against an earthen embankment for a sufficient time to saturate it, there is always considerable seepage caused by the river water percolating through the pores or interstices of the embankment. The amount of seepage is usually governed by the porosity of the soil composing the embankment. Seepage is not usually free in embankments composed of clayey materials; when seepage does seem to exist in them to a considerable extent, it is more properly leakage due to cracks in the embankment caused by contraction in drying out or to unequal shrinkage. Seepage is freest in embankments composed of sandy soils; the coarser the grain of sand the freer the seepage, because the soil does not become sufficiently compacted during the time the embankment is constructing to render the mass impervious to water. Voids are of large or small size, depending on the coarseness of the grains of sand. Under water pressure the voids soon become connected and form numerous minute channels, which wash and enlarge as the flood is prolonged or the pressure increased by greater height.

Seepage produces a general softening or rotting of the land slope of the embankment. The soil at this point often becomes semi-fluid, and, if the slope be steep, a part of the embankment will slough or slide out, producing a corresponding loss of cross-section. The writer has never known a first slough to extend higher up than one-half of the slope of the levee. If the seepage be not stopped, a second slough will occur higher up as soon as the face made by the first slough has been reduced to a semi-fluid condition; this action will progress in steps until the embankment has sloughed across its entire cross-section as far as the water. Its action being progressive, sloughing does not constitute an element of great danger, for there is always ample time to stop it; treatment is simple if the principles involved be understood.

To arrest sloughing, good land-side drainage and stoppage of the seepage are essential. A competent drain ditch should be cut, about 2 feet clear of the base of the levee, to conduct the seepage water as frequently as possible to some natural line of drainage in the rear of the levee. Additionally, numerous small V-shaped gullies, an inch or so only wide and deep should be cut in the land slope of the levee to promptly deliver the seepage water to the drain ditch. The position and size of the drain ditch and gullies should be such as to assure the removal of the seepage water as fast as it comes through the embankment, for if this water is allowed to stand, the land slope will not become water-soaked and its integrity will be preserved.

The next step is to stop the seepage; this is effected by dumping loose earth into the water in sufficient quantity to cover the submerged front slope with a blanket of fresh soil several inches thick, the coarser particles of which will be sucked into the interstices or small channels. These soon expand from wetting, and shortly the seepage will be "choked." The layman who sees this work in progress will immediately classify dumping loose earth in the water as sheer nonsense, but, as a matter of fact, the good effect will manifest itself in a short while after work has been commenced: at first by reduced seepage, a little later by entire stoppage and ultimately by the mass drying out and showing no further inclination to move.

If sloughs be treated when they first occur, or, better still, before they occur, when their approaching occurrence is clearly indicated to the experienced eye by the presence of excessive moisture on the land slope, much annoyance and expense can be avoided. As the treatment of sloughs is necessarily expensive when a number occur in close proximity and the supply of labor is limited, they may be only partially instead of wholly treated: that is, in lieu of putting a large enough blanket of loose earth on the river slope of the levee to provide against further seepage during the entire flood period. Only a small blanket need be put on, just enough to stop the seepage for a few days. The wheeling runs should be left in position, and, as soon as seepage again manifests itself, work should be resumed until the flow is once more stopped. In this way a force of fifteen to twenty men may be kept nearly constantly employed working from slough to slough.

It is usually the case, when a slough occurs and an inexperienced man tries to correct it, that he will endeavor to restore the lost cross-section with earth or sacks. This does no good, but rather tends to augment the trouble, because the slough is thereby rendered more difficult to drain, and at the same time that much more weight is put on the semi-fluid mass to squash it out, which invariably pulls with it some of the remaining good embankment. He does this because he does not understand what produces the slough. He does not know that it is caused by too free leakage through the embankment and inefficient land-side drainage.

The writer received his first lesson in treating sloughs by observing men at work about a fleet of coal barges. If a barge starts a seam leak, it is impracticable to dig away the coal to get at it. It is equally impracticable to detect the leak by feeling along the outer or water side of the barge, as the inflow is too light to be detected by the hand, and then, again, as a loaded barge draws

from 8 to 9 feet of water, it would oftentimes be impossible to reach the leak by hand. But the coal barge man has a supply of coarse sawdust, and by means of a long handle, to which it is attached, lowers a cup of sawdust in the water within close proximity to the leak, shakes it gently, just next to the barge, and, as the sawdust floats out of the cup, some of it is drawn into the crack and becomes lodged; it very shortly gets wet and swells, and the leak is choked. The same principle applies to stopping sloughs.

SINKING.

Sinking embankment is treacherous and requires the most careful attention and the exercise of good judgment in its treatment to prevent disaster. It is treacherous because its action is sudden and not always attended with premonitory signs, and good judgment must be exercised in treating it, lest the remedial measures prove destructive. A troublesome feature which attends the care of a sinking levee is that it is invariably situated in an ill-drained swamp, which soon fills up with seepage or rainwater, and earth with which to repair it is not immediately accessible, having generally to be transported a long distance on barges. At the present time there are only two lengths of sinking levee in the Fourth District. One of them, which covers about 2000 lineal feet, is at Kempe in the Lower Tensas District, and the other, which is a small affair about 50 feet long, is at Point Manoir in the Atchafalaya District.

Several sinking levees, of greater lengths and attended by subsidence of greater extent than the two levees just named, have been experienced in the past, but after much work they were made secure. The most aggravated cases of sinking seem to have a limit of subsidence, and it is only a question of continuing to pile on earth to secure a substantial embankment. The levees at Kempe and at Point Manoir should therefore be made secure in time.

A levee sinks because it is built on a foundation composed of quicksand or some other equally soft or semi-liquid material, the power of which to sustain weight is governed by the degree of moisture contained at the time the weight of the embankment is put on. It has sometimes occurred that the sustaining power has, during construction, been sufficient to support the embankment, and no movement has taken place until some later date, when the strength of the foundation has become impaired by being excessively wetted.

It has been the general experience, however, that all aggravated cases of sinking levee have been attended by considerable subsidence during construction.

As the weight of the embankment is the direct cause of the sinking, care must be observed not to add, during a flood, more earth than is actually necessary to hold the water. As the embankment subsides, the very lightest possible addition should be made to maintain an elevation several feet above the water surface and the narrowest width of cross-section that will resist seepage. This will entail almost continuous work of small amount rather than a large amount at intervals. It must not be forgotten that if a large amount of earth should be added in a short space of time, the rate of sinking will be accelerated, and the addition will do more harm than good.

Sinking embankment seldom subsides uniformly. Parts of it sink faster than others, causing the levee to crack longitudinally. There is usually one large crack along the crown of the levee, though sometimes other but smaller parallel cracks occur. Care must be taken to keep the water excluded from all or as many of the cracks as possible, particularly the largest one. As soon as water enters a crack, hydrostatic pressure is exerted on the section of embankment in the rear of the crack, and the remaining embankment in front of the crack is rendered valueless as a factor of strength in resisting the pressure of the river. For this reason the addition which is made to keep the top of the levee above the water surface should be placed as far as practicable to the water side of the crack. Lateral cracks which would let the water into the longitudinal cracks must be guarded against and immediately stopped if any occur. If, as is somewhat common, there is seepage through a sinking embankment, prompt measures must be taken to remove the seepage water in the manner described for treating sloughs. As much depends upon keeping the levee dry, it is advisable to spread tarpaulins on the entire sinking levee or at least cover the large cracks while rain is falling, to prevent wetting and to exclude rainwater from the cracks.

A sinking levee may be compared to a sick baby, and requires the same continuous attention and care. As only a small margin of safety exists, a competent force, equipped with ample materials, should be retained at the levee night and day, prepared to care for emergencies at a moment's notice.

WAVE-WASH.

Wave-wash is common on levees exposed to full wave action and not protected by a close growth of grass or some artificial device. It is a much overrated danger, and has been the cause of the needless expenditure of large sums of money in the past.

Wave-wash is misleading in its appearance; in nearly every instance its worst feature is visible, but the inexperienced invariably conceive the idea that the vertical face made by the wash extends to the base of the levee and that the cross-section of the levee has been so much reduced as to seriously endanger the embankment. As a matter of fact the deposed soil settles into position just under the water surface and the reduction of the cross-section is no greater than is apparent above the water surface.

There was a time in the past when the cost of moving earth was comparatively high, and it was less expensive to prevent a part of the levee washing away than to allow it to wash away and afterwards replace it. But this condition no longer exists; under ruling prices for moving earth it is cheaper to restore wave-wash than to prevent it with revetment. Revetment should therefore not be resorted to until the safety of the levee is endangered, which, in the writer's opinion, is not until the crown itself has been attacked. It is accordingly recommended that no steps be taken to arrest wave-wash until the vertical face it cuts has reached the river edge of the crown of the embankment.

When revetment is used, as its service will be but temporary, the most inexpensive structure should be employed. Such a structure consists of posts 3 x 3 inches or 4 x 4 inches, driven into the river slope of the levee and inclining towards the levee at an angle of 15° to 20° from vertical; the upper end of these posts should be rendered immovable by 2 x 6-inch braces connecting them with a short piece 4 x 4 inches or 2 x 6 inches, called an "anchor," driven in the crown of the levee. The posts should be placed not more than 6 feet apart, to give the structure sufficient rigidity to resist the buffeting of the waves. To the outer face of the post must be nailed 1 x 12-inch boards, laid horizontally, care being taken to have the bottom board everywhere throughout its length rest firmly on the slope of the embankment to prevent under wash. It is not usually necessary to maintain the boarding higher than 2 feet above the water surface to provide against destructive overwash. If revetment be placed in the early stages of a flood, the posts should be made long enough to stand such additional plank as the rising river may afterwards necessitate.

EXCESSIVE EROSION AT SALIENT ANGLES.

This is a danger which is not often encountered, and it may be easily provided against; its existence is directly due to the inexperience or inattention to duty of the constructing engineer.

Acute salient angles are rarely put in new levee lines; the

most acute angles put in new levee lines are the re-entering angles. Acute salient angles in the controlling line of levee are usually found at the junction of a new levee with an old one. If such a junction occur behind a sharp point in the line of the river, it will be subjected to excessive velocity of the current. When the river is extraordinarily high, the distance across a point is so much shorter than the length of the channel around the point that the river pours across the point with increased velocity. This excessive flow should be restrained from exerting any influence on the controlling line of levee by leaving the old levee, which the new levee adjoins, undisturbed for several hundred feet from the junction. In building new levees it is a common practice to cut away the old levee, which may be nearby, to secure better building material and at the same time to reduce the length of haul. There is generally no objection to doing this, but in cases of salient angles, which, under the circumstances above related, would be exposed to excessive wash, the practice should be omitted.

If, however, a salient angle should be washing at a dangerous rate, the wash may be arrested by constructing a wing dam to check and divert the current. A suitable and inexpensive wing dam consists of a crib similar to that described under the head of "Leaks," built at an angle of about 45° to the axis of the flow on the upper side of the salient angle. The wing dam should be commenced at a point on the levee about 50 feet above the angle, and extended so far that its outer end reaches to or overlaps the salient.

CUTTING.

Cutting a levee by malicious or insane persons can be prevented only by closely guarding the line while the water is near enough to its top to permit the work of cutting to be done in a short time. Remedial measures are of no avail; preventive measures alone must be employed.

EQUIPMENT AND ORGANIZATION.

To execute most economically, as the exigencies of the situation demand, any of the various kinds of work which have been described, suitable tools and materials and ample labor under competent direction must be at hand. As has been stated, much waste has resulted in the past from the use of other than the materials best suited because the most suitable materials were not available, and from incompetent direction of the work. In protection work, as in other things, "a stitch in time saves nine." Much expense may often be avoided if a weakness be discovered in its incipiency and promptly corrected.

No high-water protection system can be complete without good transportation and good communication facilities. To make tools and materials readily available, supply depots should be established every five miles along the levee line, and these depots should be connected by telephone service.

Each of these depots should be provided with a house in which to store tools and materials and incidentally to furnish sleeping and eating quarters for watchmen and workmen; each depot should be equipped with two small flatboats to move tools and materials to points where they may be needed.

By the time the river has reached 42 feet at Vicksburg, and, later on, 42 feet at Red River Landing, there should be an inspector in the field having general supervision of the high-water work for about 135 miles of levee line. He should keep constantly moving over the line to instruct his assistants and to see that they properly discharge their duties; he should also keep himself informed as to the materials on hand as well as those which may be required.

Under his direction there should be inspectors having local supervision of the work on 20 miles of the levee line each. These men should inspect every foot of the levee line on their beat at least once in every twenty-four hours. As soon as they arrive on the ground, the embankment should be thoroughly cleared of all weeds and coarse vegetation, and the grass should be mowed close to the surface in order to fully expose the entire surface to the closest scrutiny. At the same time, existing drain ditches near the land base of the levee should be cleared and put in good order. If such ditches do not exist they should be promptly cut. As the river rises, or the amount of protection work increases, the 20-mile beat should be reduced to such a length that the inspector can inspect every foot of it daily, and otherwise give it proper attention and competently direct all necessary work.

Whenever the water in the river gets within 3 feet of the crown of the embankment, a reliable day and night watchman, in addition to the inspector, should be placed on every $2\frac{1}{2}$ miles of the levee line, and the watchmen should be required to constantly patrol their beat during the night as well as during the day. If dangerous places develop, no matter what the height of the river may be, a day and night watchman should be retained at each of such places in addition to the patrol watchman.

OBITUARY.

Charles E. C. Breck.

By Joseph H. Curtis and Channing Howard, a Committee of the Boston Society of Civil Engineers.

[Read before the Society, March 21, 1900.]

Mr. Charles Edward Cushing Breck was born in Milton, May 8, 1834. He was educated in the public schools of the town, and took a supplementary course at the Milton Academy. At the age of twenty-one he engaged in land surveying, in Milton and adjoining towns, with his father, the late Charles Breck.

In 1862 he assisted in forming and enlisted in Company B of the Forty-fifth Regiment, Massachusetts Volunteers. He was first a corporal, afterwards a sergeant, and served creditably until the return of the regiment from service. After his return from the war Mr. Breck engaged in farming and floriculture until 1870, when he formed a partnership with Herbert T. Whitman, as civil engineers and surveyors, under the firm name of Whitman & Breck, which partnership continued until 1885. As a member of the above firm he was very actively engaged in the business of his profession in Boston and suburbs, and in New England in general, in these fifteen years doing a very large amount of work.

During this period the firm did considerable steam railroad engineering, including the construction of the Boston, Revere Beach and Lynn Railroad, which was accomplished in a remarkably short space of time, presenting, as it did, most of the problems of a longer section of railroad; also including the construction of the Winthrop Branch Railroad, the beach railroad from Point of Pines to Point Shirley, work on the Manchester and Keene Railroad, the Harwich and Chatham Railroad, the proposed Boston, Lawrence and Haverhill Railroad and a proposed elevated railroad system for Boston and suburbs. A general engineering and surveying business of considerable magnitude was maintained during these years, many properties of successful land companies around Boston being laid out and developed, notably at Winthrop and on the North Shore.

After dissolving partnership with Mr. Whitman, Mr. Breck continued to practice his profession actively as a civil and landscape engineer. He was engaged in the construction and surveys of many public and private grounds, and served as commissioner for abolition of grade crossings, etc.

During about thirty years of business in Boston Mr. Breck occupied only two different offices,—viz, at 209 Washington street, and at 85 Devonshire street. Mr. Breck lived nearly his whole life in Milton, Mass., and served several years on the School Committee and other committees, but was not generally ambitious to hold public office.

In 1894 Mr. Breck suffered from an attack of the grippe, and never fully recovered his health. His death, from apoplexy, occurred January 29, 1899.

Mr. Breck was married, in 1857, to Mary S. Stone, of Belmont, who, with three daughters, survives him. He was a member of the Boston Society of Civil Engineers, of the Boston Veteran Firemen's Association, Macedonian Lodge, F. and A. M., of Milton, and Huntington F. Wolcott Post 102, G. A. R., of Milton.

Mr. Breck was a most companionable and genial gentleman, always ready to oblige others, even at a sacrifice of his own time and interests, and his genial presence will be much missed and mourned by all his professional and other associates.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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SHOP AND MILL INSPECTORS AND THEIR WORK.

BY W. O. HENDERER, MEMBER OF CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, September 11, 1900.*]

MANY years ago certain truths were expressed by a noted public speaker from which there originated the famous motto, "Eternal vigilance is the price of liberty." By changing one word, and making it read "Eternal vigilance is the price of safety," the motto is rendered no less true and trite, for in this world of ours every man must be vigilant and alive to his own interests to succeed. How many men when buying any article or commodity would feel that they were secure in their purchase if they did not, either themselves or through an agent, assure themselves that they were to get what they paid for?

Watch the careful man when he buys a pair of shoes, for instance. He first decides just what he wants, then he goes to his dealer and states his wishes. The shoes are brought forth; he looks them over, and if they are good shoes and of the quality he desires he accepts and pays for them. In his dealings with the shoe man, then, his procedure covers two things,—specification and inspection.

So it is when a man or a corporation buys a bridge, a building or any structure containing iron or steel. The careful man or corporation is vigilant to his own interests and safety in assuring himself or itself that every detail is constructed just as it should be, and that the materials are of the quality he desires and pays

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for. To this end plans showing just what is wanted and specifications setting forth in detail the method of construction and the quality of the materials and workmanships are prepared. This is the specification part of the dealings. Then, when the structure is being built, the purchaser watches it, or causes it to be watched, to see that all the details and conditions of his plans and specifications are met and complied with. This is the inspection part of the work.

But in the case of iron or steel structures no cursory examination can truly determine whether the material and workmanship is all as it should be. No scrutiny of a finished piece of iron or steel can discover whether or not it is free from imperfections in its composition, and from abuse in the treatment it has received during the various processes in the manufacture of the finished parts of the structure that may seriously and even fatally affect its strength. To be sure that he is getting what he is paying for the buyer must have means of knowing that the raw materials are of good quality; that the metal when rolled contains no harmful ingredients in dangerous quantity; that the material is properly handled, straightened and finished; that the various processes incident to its manufacture into bridge or other structural parts are all properly and conscientiously done; that the parts when finished are all of proper size; that they are painted and treated as they should be; in short, he must, either himself or by a representative working in his interest, follow the progress of the material from the ore to the finished structure. Then, and then only, can he be reasonably positive that his structure is what he desires and pays for.

Such careful attention to details requires that some one be at mills at all times when material is being rolled for the work in hand to conduct the tests of all the material produced, and to measure and carefully examine the bars as they are finished. It requires that some one be at the shops during the manufacture of the parts of the proposed structure from the material received from the mills to see that all the details of the treatment it receives are in accordance with the specifications, and that the finished parts all comply with the requirements as to size and quality of workmanship.

Few purchasers can look after such things personally. They have other things to attend to. Engineers and architects in charge of structures have all they can do to superintend the other parts of the work in hand. The matter of the inspection of the materials entering into them is a detail that they must intrust to an assistant, and so men expert in this particular sort of superintendence have become useful and have found their places among the arts. The

inspector makes it his business to fully understand all the various processes and their results, and to look after his client's interests in all respects.

There was a time when one man could comfortably attend to such duties himself, and personally follow the progress of the material in all its various processes. The shops and mills at which iron was manufactured and where the finished parts of structures were produced were often one and the same, or, if not, the processes followed each other in such rotation that one man could get from mill to shop and keep proper consecutive track of the work. But the industry has of late years grown to such enormous proportions and has extended over such a large area that it is impossible for one man to properly inspect the work in all its stages. Bridge companies now have a number of mills from which to order the material necessary for their work. They are likely to have plates from one mill, beams and channels from another and other shapes from still a third; and the mills are often great distances apart. Frequently, too, the shop is at work on some portions of a contract while the mills are still furnishing materials. It is manifestly out of the question for any one man to thoroughly inspect work at all these places at one time. He must have assistance in some way.

Men who have become expert and experienced in this sort of work have made inspection their particular business, performing this service at a compensation based on the tonnage in the work, instead of entering the service of the engineer or architect in charge at a salary. Such men, as they found it impossible to economically perform their duties personally on account of the excessive expenses of traveling about, adopted the method of reciprocating among themselves, an inspector in Pittsburg undertaking to do the mill inspection on one piece of work for another located in Philadelphia, while the latter attended to shop inspection at shops in his vicinity for the former. Naturally, from such alliances among inspectors, there has resulted the formation of inspection bureaus or companies. Such companies employ men permanently at the various mills and shops, and maintain extensive general offices, at which the clerical work of copying and forwarding reports of tests, progress of work, etc., is performed. By securing large quantities of inspection work they are able to keep good men at all the localities necessary, maintaining a perfect system of effective inspection and giving their clients regular reports of the quality of material and workmanship and the progress of the work, and information as to tests, shipments, etc., which, when completed, comprises an accurate record of the structure in question and surety that it is built as it should be.

Such a company, to be effective and to economically perform good service, requires the most careful organization among its corps of inspectors and clerks. Detailed systems for the handling of such work have been adopted by some companies as the result of much study and experience, and the inspection of various classes of work for clients in all parts of this country and abroad, done at mills and shops in all the centers of manufacture, is performed with the machine-like regularity and uniformity which alone is the safeguard against mistakes, lost records and careless work.

The following brief description of the methods adopted by the inspection department of the Osborn Engineering Company, of Cleveland, Ohio, one of the principal inspection bureaus of this country, will illustrate the care taken to give all work the closest attention, to keep track of its employes and to insure the best results to its clients.

When the contract for a bridge or for any other steel or iron structure is let the inspecting company and the contracting bridge company are mutually notified. The former is supplied with a copy of the strain sheet and general plans and specifications. These are first examined at the inspecting company's general office, and any necessary notes made of special features, and then sent, with instruction slip A attached, to their inspector located at the contractors' shops. When the bridge company places its orders for material with the various mills copies of these orders are sent to the inspecting bureau, where they are copied in duplicate on the blanks C, one copy of which is sent, with instruction slip B attached, to the inspectors located at the various mills where the material is to be rolled. The weights of the various items of material ordered are estimated and entered in the other copy, which is retained at headquarters for future reference.

Each mill inspector first carefully compares his copy of form C with the mill order book, to see that no changes or mistakes have been made in ordering. As fast as the steel is manufactured test specimens are taken by the mill inspectors and the necessary tests are made, the report of tests on each separate blow or melt of steel being sent to headquarters, together with data from the mill chemist's certified report of chemical analysis on the inspector's test slip D. Drillings are also taken, when required or deemed advisable, from the test pieces and sent to headquarters, where check analyses are made in order to test the accuracy of the mill chemist. The test slips D are collected at the general office and copied on the test report blanks E, which, after press-copying, are sent to the engineer or architect. While the material is being

rolled into the shapes ordered the inspector is constantly on hand, and from time to time he calipers and measures the pieces to see that they are of the requisite size and thickness. He sees that the bars are properly straightened and cared for while cooling, and that they show no flaws or ragged edges. As fast as each bar is inspected and found satisfactory he strikes into it a distinguishing mark of the inspecting bureau furnished him from the general office, which signifies that the piece has satisfactorily passed his examination and is composed of material the tests of which have been satisfactory. The stamp he uses, besides the distinguishing mark of the inspecting company, bears a number, and this number is recorded in the general office against his name. He keeps this stamp closely by him at all times, so that there can never be any question as to who performed the inspection on any piece of material. He keeps his general office informed regarding the pieces he has inspected from day to day on any one piece of work by means of the report F. As fast as the material is shipped from the mill he forwards to the general office, after he has checked them, the tissue copies of invoices furnished him by the mill. There the items and weights are checked against those on his report F and against the copy of form C retained at headquarters. The invoices are then copied on the blank G, which is sent to the engineer or architect after press-copying.

Thus the engineer or architect in charge of the work is kept reliably informed just what material has been rolled and shipped, and he knows exactly what the results of all the tests performed on the material have been and what powers of resistance it can be expected to develop. He is protected from any fictitious claims of a delinquent bridge company of delay at the mills. The inspecting bureau has detailed records of the dates on which inspection was performed on any lot of material, and is protected against fictitious claims of delay in the inspection of material at the mill.

As soon as the material begins to arrive at the contractor's shop the shop inspector located there begins making regular weekly reports on the work in hand to his general office. He has, in the meantime, received from the bridge company a full set of the working drawings of the structure. He has carefully checked them against the general plans received at the outset, and has called attention to and had corrected any errors in them or differences between them and the general plans furnished him as his guide. He has also made a careful estimate of the weights of the various finished parts, and a list of all the parts that will be required according to the contract.

It is his duty to be constantly on hand about the shop during the progress of the work, watching the various processes and seeing that everything is done according to the specifications that have been furnished him. He sees that only material bearing the mill inspector's stamp is used, and that it has arrived from the mills in good condition. By watching the processes thus closely he is not only able to detect faulty work which would be covered up when the piece is finished, but he can often save both the bridge company and his employers considerable time and expense by noting mistakes early, while they may still be corrected readily and at little cost. When a piece is finished he makes careful final examination of it, comparing all dimensions with the plans, testing the riveting, etc. It is then painted under his superintendence, and he stamps in the piece, in a conspicuous position, a similar distinguishing mark to that used by the mill inspector to indicate that the shop work has all been properly done and that the piece is as it should be in every respect.

The shop inspector's weekly reports come to the general office in three forms, H, I, and J being respectively his report of material received from the various mills, of the work performed on the structure in the shop and of finished pieces shipped from the shop to their destination during the week. Form H is first checked against form G, and then the three forms are press-copied and sent to the engineer or architect. The method of reporting the condition of the various members of a structure from week to week on form I may require more detailed explanation. The first column, headed "required," shows the number of pieces of a particular mark required. The number in this column remains constant from beginning to end. The other columns show what stage in the process of manufacture each piece has reached each week. Thus in a bridge there may be four end posts required marked aB. The figure 4 would then appear in each report in the first column. One week there might be a 4 in the third column, a 4 in the fifth and a 2 in the next to last, showing that all were assembled, all riveted and two finished awaiting shipment. When the same figure appears in the last column as in the first all the pieces of that kind have been shipped, and when all the pieces required for the work are shown in the last column the material has all been finished and is on its way to its destination.

For every shipment of material copies of the shipping bills, giving the itemized scale weights of the material on each car, are furnished the inspector by the bridge company. He first makes a note of these items and weights, checking them against his list of

parts required to complete the work and the estimated weights he has. He then sends the bills to the general office, where they are copied on form K, which, after press-copying, is sent to the engineer or architect. Reports of tests of full sized eye-bars for bridges are made out on the blank L, press-copied and sent to the engineer. Form M is similarly used for reporting results of tests of cast iron.

When a job is finished a final report is sent to the engineer or architect, stating briefly the work that has been done and noting any unusual features that have developed during the inspection of the material or cases where material was rejected. This report usually includes a summarized statement of the weights of the finished parts, comparing the estimated with the actual scale weights to show whether the various parts have been accurately proportioned in accordance with the drawings, and also a statement of the shipments made, giving dates of shipment, car numbers and initials and weights.

The engineer or architect then has a complete record of the material used on his work, the dates on which the shipments were made from mills to shop and complete records of its progress through the shop and of the shipments from the shop to the building site. With the exception of the slips and form D, all the reports and blanks used are uniformly of letter size and printed on thin paper. They are thus in the best possible shape for filing, and do not make an unnecessarily bulky package. The final report embodies all the points necessary for ordinary cases of future reference. The inspecting company has not only duplicates of all these documents carefully preserved, but all the detailed information of all kinds relating to the work are carefully filed with the copies of reports, correspondence, etc., and stored safely away, thus forming an additional safeguard against loss of records. If at any time in the future information should be wanted concerning the work, if repairs are to be made, or if any question arises as to the strength of the structure, the inspecting bureau can furnish the information if necessary.

One other of this company's many forms may be interesting. Form N is a blank form of diary furnished to all its employes, wherever located. The employes are required to keep thereon a concise diary of their doings and movements, and note the time spent and expenses chargeable on each piece of work. At the end of each period these are sent to the general office, where they are checked over and the time and expenses of each man entered against each job. The company thus has a pretty good check on

each man as to whether or not he is attending to his duty and spending proper time on each piece of work allotted to him.

The employment of competent inspecting bureaus becomes more and more general as the iron and steel industry increases in volume and competition between the manufacturers grows keener. Men are realizing more and more forcibly the necessity for such services in order to insure good results. The day when people thought that because a bridge was built of iron it would stand indefinitely and support any loads that might be imposed is past and gone. Men are finding that there are good and bad iron and steel, and that there is so great a difference between them—often the difference between success and failure, between a strong, stiff and durable structure and an accident costing human life—that it pays to spend the small added cost to insure the use of the good material and to detect and exclude the bad. Nearly all the best structures built to-day are manufactured under the watchful eyes of inspectors employed to see that the provisions of the specifications are strictly followed.

But, unfortunately, this class comprises by no means all the structures built. There are great quantities of iron and steel structural material produced and made into bridges, buildings and other structures on which human life depends that are not so inspected, and concerning which the purchasers have no assurance as to their strength or durability because they have no knowledge of the quality of the material or of the treatment it has received during its manufacture. Thousands of tons of steel are annually manufactured and sold to people who have no way of knowing anything about its quality. Hundreds of bridges and buildings are built every year out of such material, and no one can tell whether or not they will actually stand the strains they are intended to stand. Is the general public to blame when it assumes that such a structure is capable of successfully withstanding the loads and shocks it is called on to resist? Can a man do otherwise when he enters a building or crosses a bridge than place confidence in the care and thoroughness with which its architect or engineer has attended to all the details of its construction? Accidents happen, much more frequently than they should, that are traceable to bad material or workmanship; generally both. If the structure that collapsed had been inspected by competent men such accidents would not have occurred. There is yet to be recorded a single case where a structure properly inspected by inspectors who know their business and do it honestly has failed under the loads it was designed to carry, while, on the other hand, there are many engineers and architects

who can testify to important saving of time and money through the employment of competent inspectors.

It is remarkable that so many fail to see that specification and inspection must always go hand in hand; that neither can confer the benefits it should without the other. Most people realize that if no specifications are stated to indicate the nature and quality of the structure desired the manufacturer cannot be blamed if the structure does not meet the expectations of the purchaser. But often little thought is given to the second part of the purchaser's duty, that of inspection. It is not recognized as a duty owed by every purchaser for his own protection and safety, and to secure benefits from a carefully compiled specification. When the millennium is reached, when it may be reasonably expected that every man's work will be perfect and each one's labor as valuable as that of his fellows, then there will be no difference between good and bad, no possibility of errors or mistakes or dishonesty. When that time arrives there will be no further use for either specifications or inspection, and many a busy man will lose his job. But until that time there will be varying grades in the quality of materials and workmanship, and the necessity for specifying the grade desired on any piece of work will remain. And just so long as there is any cause or reason for specifications, just so long will the inspector be needed to see that the specifications are carried out.

There are various reasons advanced why such inspection service is not employed. Most of them may be classified under the four classes discussed below.

First. Some believe that by placing their work with the best-known bridge companies they are so sure of satisfactory results that no check on the quality of the work turned out is necessary, and that by availing themselves of such a check they are casting unpleasant reflections on the honesty of the bridge company. This is far from a correct view of the case. It is not a question of the integrity of the bridge company or of its management; they may have the best of intentions. But what of the many men through whose hands or under whose eyes the tons of material must pass in its progress from the ore to the finished structure, each one of whom leaves upon it, for better or worse, the results of his work. Each man will look to his own personal interests first. It matters not to him if the material suffers, so long as he can save himself from the consequences of the discovery of his bad work. Besides, it is human nature for a man to underrate an error made by himself. His judgment is warped by his financial interest, and he is apt to think "it is good enough." Thus when a man makes a mistake or

botches a piece of work he is tempted to hide his error in order that his reputation with his foreman may not suffer. He knows that each error made and discovered lowers his value in his employer's estimation. Frequently employes are paid by the piece or ton, the workman then becoming practically a sub-contractor with no interest in the work beyond doing it well enough to get his pay for it. His interest lies in doing a large amount of work; in the production of quantity even at the expense of quality.

Foremen, and even superintendents, will frequently pass flaws and errors that their reputation for executive ability may be maintained. A manufacturing firm looks to its superintendent for results. Time taken to correct mistakes or replace faulty material means decrease of output, and if the output decreases cost increases and the superintendent must explain. So the work is hurried through the shop with speed of completion the principal end in view, and if the foreman or his superintendent notices a defect he is tempted to let it pass for the sake of keeping up the rate of output and saving the expense and time of correcting it.

It is often easy in walking through a bridge shop to tell at a glance which of the various pieces of work in progress are in an inspector's care and which are not. The difference is often apparent to a casual observer. Some bridge companies make it a rule to mark plainly on all their working drawings whether the work is to be inspected or not, and by whom. In this way the workmen have the best of means of estimating the chances of bad work passing unnoticed. The excuse is sometimes made by a shop foreman when a blunder or careless workmanship is brought to his attention by an inspector, "I was not told that this piece of work was to pass inspection."

Some shops maintain on their pay rolls an inspector whose duty it is to examine the work as it comes from the shop and report errors. His duty is performed when the work is finished; he has no jurisdiction in the shop while it is going on. Errors committed and covered up are beyond his detection, and he assumes that they do not exist. But even as regards the errors that may be discovered after a piece is finished, it is human nature for such a man to consult his own interests first and to perform his work in such a manner as best to serve the interests of the people to whom he looks for his pay. When he discovers a mistake in the fitting together of pieces, rivet holes left out of joints, or such like errors, he will report them, because he knows it will cost his employers much more to correct them in the field when they erect the structure than at the shop before the material is shipped to its destination. But he

will be indulgent in such matters as loose rivets, buckled web plates, unannealed forged members, careless painting and the details of construction that may be either good or bad without of a certainty causing his employers trouble later. He casts his lot in with the rest and risks the results, and that such risks are real let accidents on record bear testimony.

Such an inspector is generally some man taken from the shop, some good mechanic who can read a drawing and make an accurate measurement. He is paid little if any more than the men who are doing the work he is called upon to examine, and he draws his pay from the same window and standing in the same line with his fellows. He probably belongs to the same labor union, and is closely associated at all times with the very men who are laying out the work, punching the holes and driving the rivets. It would not be good policy for him to be the cause of too frequent scoring of such men. It might be dangerous for him to be the cause of their discharge.

As to reflections on the honesty of a bridge company cast by the employment of expert inspectors by the architect or engineer, no company honestly trying to do good work has such a feeling. If the inspector knows his business he will not interfere with the men at their work, nor will he cause the company unnecessary trouble in any way. He will be quick to detect errors and see to their correction; often his experience will be of material benefit to the foreman in suggesting the best method of making the correction. The inspector relieves the men from many cares in the performance of their duties, and the bridge company that has nothing to fear from the inspector will welcome him to the shop because he helps them to see that their work is done in the best possible manner and to keep up their standard of perfection in the structures they manufacture.

A few years ago a bridge was built, shipped to its destination by the bridge company and nearly erected before it was discovered that certain important parts necessary to complete it had been overlooked; had never been made in fact. It was during the freshet season, and to save the bridge from being washed away temporary members were devised on the ground and the span fortunately swung before the falsework went out. When the missing parts arrived new falsework had to be built, the span jacked up and disconnected and the new members inserted. Such blunders as this cost money. An inspector who knows his business and diligently attends to it can be the means of avoiding such blunders, and not only of saving his employers time and trouble, but of saving the bridge company from the expensive results of errors.

Second. Some think that the extra cost of inspection adds too much to the cost of the work. They prefer to pay the bridge company its price and run the risk of getting a poor job in return, rather than pay a slight excess to an inspecting firm and have assurance that they are getting good work. They willingly pay a liberal premium in the stock market for bonds of good repute, rather than buy others for less money. And yet is it not cheaper to pay $102 for an article known to be worth $100 than to pay $100 for an article that may not be worth $75? The cost of inspection, by competent experts who make it their duty to watch every detail of the manufacture and check all the plans to see that everything has been done as the architect or engineer intended it should be done, should not exceed 2 per cent. of the total cost of the steel work. Is such a percentage a high rate of premium to pay for the sake of security?

Not only is good inspection worth what it costs to the owner of a structure on account of the security he is warranted in feeling as to its efficiency, but it is a duty owed by every corporation owning structures on which human life depends to take every possible precaution to secure the safety of such structures. It is a good thing for a railroad manager to have inspectors' reports on file concerning his bridges. In case of accident to any bridge, and the often resulting damage suits, one of the first questions asked will be, "Did you have your work inspected, and by whom was the inspection performed?" Several recent suits resulting from accidents to bridges and buildings have developed the fact that no competent inspecting bureau had been employed during the construction, and the testimony has in every case reflected very unpleasantly on the carelessness or gross neglect of the engineer or architect.

Not long ago, in the construction of a railroad, a bridge was required across a certain stream. The railroad company had faith in the bridge company to whom the work was let, and saved the extra cost of inspection. That bridge collapsed within three months after its completion. Subsequent examination showed that not only was the work built at the very lowest limit of safety as regards design, but the material was dangerously high in phosphorus. Careless shop work was admitted, resulting in the punching of clover-leaf rivet holes; and, to crown all, a mistake in marking the pieces had resulted in the interchange of members, a light one being placed where the strain sheet called for a much heavier one and *vice versa*. That accident cost the lives of three men, to say nothing of delays and expense in replacing the structure. Yet

the railroad company justly felt itself lucky, for an excursion train had passed over the bridge but a short time before. It is remarkable, but not at all surprising when the truth is known, what a large proportion of the accidents occur to new structures.

Third. A common claim by the bridge company to the architect or engineer, to influence him against the employment of an inspector, is that there will result serious delay in the completion of the work, owing to the time required for the "perfunctory" duties of the inspector. Extraordinary claims along this line are sometimes made on the part of a bridge company after work is completed, and the inspector is called upon to explain why the delay was caused. Such explanation is seldom necessary from a competent bureau, because, in the first place, the regular reports of the bureau will show the rate of progress of each piece through the shops and just where and when and how any delay was caused by any one or by any cause. In general, however, the claim on the part of the bridge company is pertinent, for the bridge company making such claim generally has reasons of its own for making such statements, and it will generally be found that at such shops delays are actually caused by the inspector on account of the time required to replace faulty material or workmanship which he rejects, and which but for his offices would be incorporated into the work to its great detriment.

Such delays are aggravating no doubt, especially when it is important that the work be finished in the shortest possible time. But it is obviously unjust to blame the delays to the inspector. The delay may mean considerable loss to the purchaser, but he can far better afford such loss than risk the consequences of faulty material or workmanship. And in any case where time is of great importance and a limit of time is agreed to by the bridge company for the completion of the work, any delay of this kind is directly chargeable to the company that undertook to furnish the materials and perform the work according to the prescribed standard within the prescribed time. It is certainly not to the inspector's interest to delay the completion of the work. He is paid for his services by the ton, and the sooner the work is finished the greater will be his profit.

Fourth. It is claimed by many that inspection as it is generally conducted is not effective; that the work is performed in so careless and slipshod a manner as to be void of the benefits it is intended to confer, and that money spent for inspection is practically thrown away.

Unfortunately, this has been but too true in the past. Inspectors worked carelessly and without system. Points which should have been detected were overlooked, and much of the work they were supposed to do was not done at all, or was so poorly done as to afford but little protection to the engineer or architect. Even now there are many who are performing their work in this careless way; undertaking to inspect a piece of work for about half what good inspection costs, and then giving the work what attention they can afford for the price and no more.

Mr. J. A. L. Waddell, one of the foremost bridge and structural engineers of this country, has had his own troubles with inspectors, as may be seen from the following extracts from Chapter XXI of his excellent little book, "De Pontibus." That whole chapter is full of interest in this connection, and will well repay careful reading. Mr. Waddell says, "For many years most of the inspection of structural metal work was a sad farce, and in consequence the general public placed but little confidence in inspection, with the result that a large portion of the bridge work of the country was left entirely to the tender mercies of the manufacturers. Latterly, however, owing to the efforts of a few first-class inspecting bureaus, the status of inspection has been somewhat improved, although it is far from being to-day what it ought to be.

"The inspection business has been utterly demoralized in times past, for it was the general custom, and is yet to a certain extent with some inspectors, to take contracts for inspection at whatever figures the purchasers are willing to pay, then handle the work so as not to lose money on the contract, regardless, of course, of the interests of their employers.

"Strange tales concerning inspection come to the ears of engineers, such, for instance, as passing carload after carload of metal work that was not seen by the inspector until after loading for shipment; but such tales need verification, which of course it is nobody's business to give them. In one case in the author's experience the inspector left his work for ten days in charge of one of the bridge company's shipping clerks, without notifying either the author or his direct employers, the inspection bureau, of his contemplated absence. Such actions as this make one entertain doubts sometimes as to whether inspection really pays."

Mr. Waddell evidently believes that inspection by competent bureaus does pay after all, since he is one of the most careful engineers to see that all his work is inspected and that the rigid requirements of his specifications are strictly followed. But he is just as careful in the choice of his inspectors.

There are a few inspecting bureaus who are striving for the improvement of inspection services, through the establishment of carefully devised systems for the thorough handling of the work and the employment of only experienced and thoroughly reliable men. Such companies can and do give the quality of service that makes inspection thoroughly valuable. But they have thus far found themselves seriously handicapped by the many irresponsible inspectors who undertake work at ridiculously low prices without any idea of doing it as it should be done. Engineers and architects are not a little to blame for this state of things, since too many of them fail to consider the inspection service as one having degrees of quality. They have become accustomed to consider that all inspection is the same, and to require that each inspector who makes application for their work shall submit his prices in competition with any one else who may be an applicant, and then employ the man with the lowest price without taking the trouble to properly investigate the comparative facilities or reputations of the applicants.

It cannot be expected that the best results of inspection will be gained by crowding the price for such services down to the lowest possible figure. There is a limit below which good inspection cannot be performed. The only way in which an engineer can get the full benefit that inspection can confer is to determine at the outset to pay a fair price for that service, and then, before appointing an inspecting firm, to look carefully into the reputations of the different inspecting companies available by references to other engineers and to pieces of work that have been inspected by them.

Thorough and complete inspection of iron and steel structural material should generally be worth one dollar per net ton of shop shipping weights. At times and under especially favorable conditions as regards the location of a bureau's employes, it can be done for less. On some small jobs it may be more, but there is in general a chance for the inspector to make a fair living at that average price. Such inspection should include the careful comparison and checking of working plans and complete supervision and tests by thoroughly experienced, expert and reliable men throughout the manufacture of the material from the time it is first produced until it is shipped from the shop.

The most experienced engineers and architects already realize that only first-class inspection is valuable. These are taking pains to see that only first-class men are employed by them, and at a fair price. Inspection bureaus who enjoy the patronage of such men are doing all their work the best they know how, and are fondly

hoping for the dawn of the day when the general public will recognize the value of the efficient service so rendered.

Good and thorough inspection can be had, but not at the low prices at which so many seem to think it should be done. If complete inspection, as above defined, is worth one dollar per ton, it cannot be expected that the man who refuses to pay that price will get such inspection.

Much of the success or failure of inspection depends on the individual ability and character of the inspector. Good inspectors are not easy to find, and when found they are worth more than the cheap bureaus can afford to pay them. A successful inspector must have a rare combination of good qualities. He must be a practical man, with long training in mills and shops. He must thoroughly understand all the details of the various processes employed, and what are the various faults that are liable to result from each process. He must so well understand these faults as to be able to detect them at once, and he must be so well informed as to know how best to correct them in the most practical manner, and when correction is not possible. But experience in mill and shop practice alone will not suffice. He must also understand enough of structural engineering to recognize the relative advantages of different details and designs. He must be able to figure out the strength of the various connections and parts, and have accurate judgment to determine just what effect a loose rivet here or a bad fit there may have in the resulting structure. He must be quick to think and act, for he is the umpire and his decisions must be prompt and fair if they are to be respected. He must, withal, be a good deal of a diplomat. The inspector who cannot deal with each mill and shop foreman in the way to best command his respect and secure his co-operation will never make a success. And, above all, he must be a man of sterling character, straightforward, upright and honest. His is a position of no slight trust, and he must prove himself at all times truly worthy of that trust.

The inspector's life is not all sunshine. He has many a disagreeable duty, and unless he has the necessary judgment and diplomacy there will be much friction between him and the men in charge of the mills and shops where his work is located. But a good, sensible man, with the qualities of a good inspector, will gain his points without engendering bad feeling; will get over the rough places tactfully, and do his work quietly and unostentatiously, but effectively. Some day the public will appreciate how important his work is, and then the inspector and the inspection business will receive the respect they deserve.

THE OSBORN ENGINEERING CO.

A

SHOP MEMORANDUM.

Job No

Name

Specifications

Contractor

Report to

" every

REMARKS

B

MILL MEMORANDUM.

Job No.

Name

Specifications

Mill

REMARKS

C

No. ....

Sheet No. ....

.... 189....

Order No. .... Contract No. ....

To ....

Contractor ....

Item No.	No. Pcs.	Description.	Section.	Length.		Weight.	REMARKS.
				Ft.	In.		

D

Date 190 , Inspector

Mill

Contract

Order No

Blow or Cast Furnace Heat

Ingot Slab Piece

Test cut from

Dims Area

Elas. Lim. Per □".

Ult. Str. Per □"

Elong. in Per ct.

Red. Dims

Red. Area Per ct.

Fracture

Cold Bend

Quench Bend

Drift Test

C Ph Mn Sul Si

Acc. or Rej.

Remarks.

E

Job No.................

Report No.................

Report of Tests of ....Manufactured by ....

For..............................Order for..............................

Reported to..............................190......

Date of Test
Blow or Melt
Furnace Heat
Test cut from
Original Dimensions
Original Area
Elas. Lim., Actual
Elas. Lim., lbs. per sq. in.
Ult. Str., Actual
Ult. Str., lbs. per sq. in.
Elongation in.........inches
Per cent. Elongation
Reduced Dimensions
Reduced Area
Per cent. Reduction
Character of Fracture
Cold Bending Test
Quench Bending Test
Drift Test
Carbon
Phosphorus
Manganese
Sulphur

Acc. or Rej.
Remarks

We certify that the above-described tests were carefully made.

THE OSBORN ENGINEERING CO.

Tested by..............................

By..............................

F

Job No

Report No.

To

The following material has been inspected at

on account of order for....

Date of Inspection

Purchaser's Order No.	Purchaser's Item No	Mill Order No.	Heat No.	No. Pieces.	DESCRIPTION AND SIZE.	LENGTH Feet.	LENGTH Inches.	WEIGHT.	REMARKS.

We certify that the above-described material has been carefully inspected.

G

Job No.

Shipping Report No.

Date of Shipment.

Shipped from

Shipped to

Car No.

Cleveland, O... 190

Purchaser's Order No.	Purchaser's Item No.	Mill Order No.	Heat No.	No. Pieces.	DESCRIPTION AND SIZE.	LENGTH Feet	LENGTH Inches.	WEIGHT.	REMARKS.

H

Job No.

Report No.

REPORT OF MATERIAL RECEIVED

189

At the Shops of On

For

Date of Invoice.	Kind.	CARS. Initials.	CARS. Number.	From.	Weight.
				Total Weight of above.	
				Previously reported.	
				Total to date.	

I

Job No.

Report No.

REPORT ON CONDITION OF WORK

190

At the Shops of On

For

Span.	Location in Structure.	NUMBER OF PIECES. Required.	Punches.	Assem.	Reamed.	Riveted.	Faced.	Forged.	Bored.	Finished.	Shipped

J

Job No
Report No.

REPORT OF SHIPMENTS 190

From the Shops of On

For

Invoice No	DATE	CARS.		DESCRIPTION	WEIGHT
		Initial	Number		
				Total Weight of above	
				Previously reported.	
				Total to date.	

We certify that the above-described material has been carefully inspected.

THE OSBORN ENGINEERING CO.

By Inspector.

K

Job No
Shipping Report No.
Date of Shipment.

Shipped from
Shipped to
Car No. Cleveland, O. 190

Contract No.	No. Pieces	DESCRIPTION	MARK.	WEIGHT	REMARKS

We certify that the above-described material has been carefully inspected.

L

Job No. ....

Report No. ....

Report of test of..Manufactured by..

From Material Rolled by..For..

Reported to..

Date of Test ....Blow or Melt No. ....

Head A.

Width ....Inches

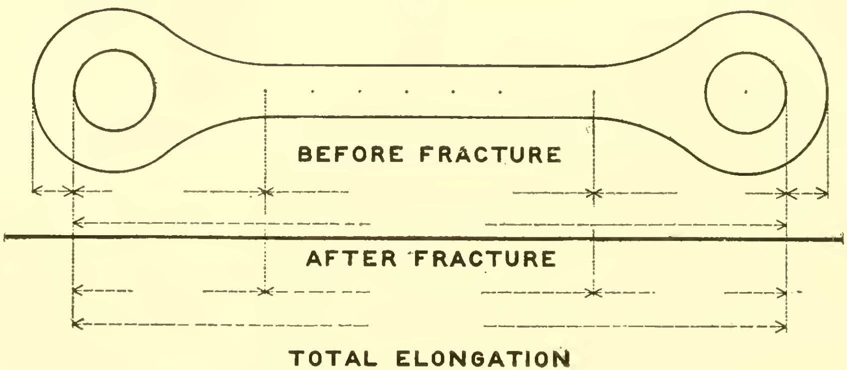
Thickness ....Inches

Dia. pin hole..............Inches

Excess........ ....per cent.

Elongated Diameter of pin

hole A ....Inches



Head B.

Width ....Inches

Thickness..................Inches

Dia. pin hole.............Inches

Excess.................. per cent.

Elongated Diameter of pin

hole B........................Inches

Elong‹tion in..12″ spaces

....

....

L (CONTINUED).

Nominal Section .... Actual Section .... ACTUAL AREA

Elastic Limit, Gauge .... Actual .... LBS. PER SQ. IN.

Ult. Strength, Gauge .... Actual .... LBS. PER SQ. IN.

Elongation; in .... inches .... PER CENT.

Elongation; in .... feet .... PER CENT.

Fractured Section .... Area .... REDUCTION .... PER CENT.

Location of fracture .... from back of Eye

Character of fracture ....

Accepted or rejected ....

Remarks ....

Specimen test from same blow or melt shows the following results:

Elastic Limit per sq. in. .... Ult. Str. per sq. in. ....

Per cent. Elong. in 8 in. .... Per cent. Reduction ....

Carbon .... Phos. .... Mang. .... Sul. ....

We certify that the above described test was carefully made

Tested on .... machine — THE OSBORN CO., Civil Engineers

At .... — By ....

By ....

M

Job No

Report No.

Report of Tests of Cast Iron Manufactured by

For .... Order for

Reported to 189

Date.	Cast No.	Specified Load.	Section.	C. to C. Bearings.	Breaking Load.	Deflection.	CASTINGS REPRESENTED.	REMARKS.

We certify that the above-described tests were carefully made.

THE OSBORN ENGINEERING CO.

Tested by .... By ....

N

DIARY

Of ....

From .... to ....

Job.	DIARY.	Hours.	Exp.	Job.	DIARY.	Hours.	Exp.
	1st.				5th.		

☞ Each employe is to fill out this form, day by day, giving complete description in detail of the kind of work done, at what place and time spent. He is also to state in detail what moneys he has expended on this Company's account, and for what purpose. At the end of the period noted hereon this sheet must be turned into the Cleveland office, giving a complete diary and statement of time and expense for the period.

NOTES ON PILE-DRIVING.

By James C. Haugh, Member Louisiana Engineering Society.

[Read before the Society, July 9, 1900.*]

The most satisfactory and reliable pile driving is where the piles are driven a sufficient depth through a material readily penetrated by the piles and overlying rock or other impenetrable material on which the points of the piles would rest. The sustaining power of the piles would then be equal to strength of the material of the piles.

Piles driven as in Fig. 1 would, according to formulas in common use, support the load of trains and locomotives. The penetration of these piles, driven into quicksand, is little or nothing for a number of blows of a 2200-pound pile hammer dropped 15 to 20 feet, yet the result, after trains began running over such pile bents, was a constant settlement of the piles, doubtless caused by the weight of trains and the vibratory motion given to the piles. Had the material overlying the quicksand been of greater depth and firmer, the vibratory motion might not have been communicated to point of piles and settlement would not have occurred.

Fig. 2 shows the conditions for pile-driving in a "pile trestle crossing" of Lake Pontchartrain. The lengths of the piles varied, in different portions of the 6-mile trestle, from 45 to 70 feet. Piles showed considerable variation in the material in which the piles were driven. The shorter lengths were driven into a hard clay, and the longer lengths through material as shown in Fig. 2. The longer lengths gave a very uniformly soft penetration, and for a number of blows the penetration was as great as 1 foot for a 10 to 15-foot drop of a 3000-pound hammer run by a friction driver and hitting short blows very quickly.

In driving these piles it was observed that if the pile giving this penetration was allowed to stand for a few hours, owing to breakdowns or other causes, it required several blows to start it, but that after it was started the same penetration resulted as before the stoppage.

The quick blows doubtless caused the material through which piles were driven to be displaced, and a cessation of driving allowed the material to resume its normal condition, with the resulting friction around the piles.

Although the trestle has been in use for over fifteen years, none of the piles have settled. Very similar conditions of driving

*Manuscript received August 23, 1900.—Secretary, Ass'n of Eng. Socs.

were met with on the $15\frac{1}{2}$ miles of marsh trestle work, where the length of the piles varied from 25 to 50 feet. The penetration of the 50-foot piles in the marsh was the same as that of the 75-foot piles across the lake. The marsh being about 2 feet above the lake level and the trestle grade being 3 feet lower across the marsh than across the lake, approximately the same penetration in the ground was obtained. No settlement occurred across the marsh trestle.

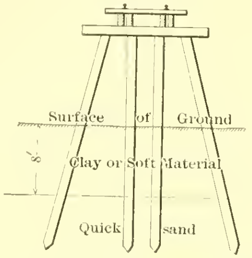


Fig. 1. Piles Driven in Quicksand.

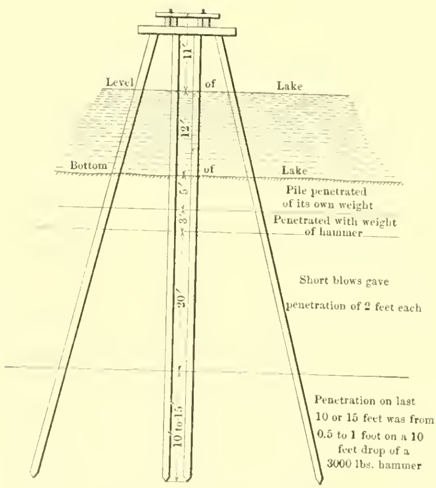


Fig. 2. Piles in Lake Pontchartrain.

The firmer material, where short piles were driven, gave a penetration of 0.20 for a 15 or 20-foot drop of a 3000-pound hammer.

Test showed that pile hammer could be so freely dropped as to give eight or nine-tenths of the same penetration as when line was cut and hammer dropped free of line from a 40-foot height.

Tests showing the sustaining power of piles driven in different portions of the city between the river and the lake would probably

show that shorter lengths of piles than the 70 to 80 foot lengths now being driven to support buildings, heavy machinery, etc., would be sufficient.

The condition of creosoted long-leafed yellow pine piles and creosoted square timber, both of the best quality and close grained, used in the construction of trestle in the lakes and coast water of Louisiana and Mississippi, shows that the lasting quality of the timber is very greatly increased by creosoting, creosoted piles and timber being now sound after eighteen or twenty years' service.

The piles used are round piles, barked and peeled, and having from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches sap wood and about 12 inches heart diameter at large end.

The square timber should preferably have sap angles and surfaces, for larger oil absorption, thus more effectually protecting the "heart wood" from decay.

The piles receive a seasoning treatment lasting from three to six hours, according to size of timber and degree of seasoning before treatment.

The timbers, on being closed in treating cylinders 6 feet diameter and 100 feet long, were saturated for an hour or more with steam from perforated pipes in the cylinders. Then the temperature was run up to from 275° to 290° F., and the vacuum pump was started, when a vacuum of 27 to 28 inches was had. All moisture was considered as removed, and timber seasoned. The creosote oil was pumped into the cylinders and kept at a temperature of from 150° to 170° F. until a pressure on oil of from 80 to 100 pounds showed that the timber was not absorbing any more oil. The time was about from four hours on 6 x 8-inch x 9-foot timber to eight hours on heavier timbers.

The "creosote oil" used is the best dead oil of coal tar, unadulterated, and having a specific gravity of not less than 1.03 at 60° F. The oil must completely liquefy at a temperature of 60° F. and boil at 410° F. or above. The oil must have not less than 50 per cent. of naphthalene.

DISCUSSION.

J. W. Hazlehurst.—In connection with the interesting discussion of this subject I should like to add a few words relating to a personal experience in pile driving for foundation work under local and normal conditions, and where the bearing value of the pile must be determined entirely from the frictional resistance of the soil acting upon the sides of the pile. Being called upon to design a water supply plant several years since for Algiers, Fifth

District, New Orleans, an item of construction was the foundation for a stand pipe 13 x 100 feet, whose total weight and stresses were found to amount to 600 tons. In order to increase to a safe permissible limit the bearing value of the soil the usual method of piling and grillage was resorted to, and 100 piles, having 12-inch diameter heads, were driven to a depth of 60 feet. The individual piles of this cluster were spaced 2 feet from centers, both longitudinally and laterally. In computing the theoretical ultimate bearing value of each pile the frictional resistance was assumed at one-half ton per linear foot of timber, reduced by a factor of safety of 5, which gave as the safe theoretical bearing of the cluster 600 tons, or a resistance equal to the weight applied. So far as has been observed, no settlement or other distortion has taken place. The individual bearing value, 6 tons, assumed for each of these piles is approximately the same as would have been obtained from the Rankine formula, where the safe bearing value is equal to the area of the head in inches multiplied by 200. Thus, if the head measured 12 inches in diameter the area, 78 square inches, into 200 equals 7.8 tons as the safe theoretical bearing for piles depending entirely upon frictional resistance for support. Some years since, in driving piling in a soft sea marsh, and where the character of the bearing material had been previously determined by water jet borings or soundings, I used this formula in determining the frictional resistance of three-pile bent work in a temporary railway trestle, and from an observation of the loads and slight subsequent settlement I am of the opinion that this formula, when used under like conditions, very nearly represents the true bearing value of piling which has no firm underlying stratum upon which to rest.

W. B. Wright.—I recall the case of a temporary railroad pile trestle one mile long (later filled in) across a piece of bottom land. This trestle was 30 feet high, and this was considered by some engineers as the limit desirable for such structures; higher trestles preferably to be built with short piling and superimposed framed bents of, say, 20 to 25 feet each until the desired height is reached. On the first work, of which I had charge, was built such a trestle 75 feet high and 1000 feet long.

Usually at a bridge site, at every 10 feet, a $\frac{1}{2}$-inch sounding rod was sunk into the ground as far as two or three men could force it. Then piles were billed to extend 10 to 14 feet deeper, and 2 feet above cut-off was allowed for brooming. Piles billed in this manner rarely went below the calculated depth, and usually gave some waste. I remember well, however, one bridge site where the sounding rod discovered 5 feet of gravel with hard bottom, but

the pile driver discovered 6 feet of gravel with a soft stratum below. In this case short piles 10 to 15 feet long, with square points, were driven and doweled, and the regularly billed piles were driven on top, giving invariably good results.

The sounding rod would not always give satisfaction. Among other deep swamps, I remember one which allowed piles to go 150 feet without reaching bottom. Such swamps will not bear a high embankment, but can often be crossed on corduroy composed of trees laid with tops lapping on the center line, on which a light embankment is built. This structure quakes when the train passes over, but gives the best of results in maintenance of way and ease on trains.

Sometimes an ordinary bank across a swamp will stand a long time without settling, or will at last seem to stop settling; but I know of one instance where a 6-foot bank that had stood for thirty years suddenly sank out of sight two minutes after the passage of a passenger train. Piling in this bank, although not giving perfect support, would probably have prevented this accident.

Piles for railroad trestles are usually driven four to a bent, with spans of 12 to 15 feet. One pile is driven vertically under each rail, and the others on the outside, often with a batter of one or more inches per foot, the driver being tilted for this purpose. Over creeks center spans of as much as 24 feet, with heavy stringers untrussed, have been used with special bents of six or eight piles.

At a division yard I once received for construction purposes a lot of cedar piles, some of which, I was astounded to see, were more than 3 feet in diameter. On making inquiries I found that the inspector, an old engineer, had been told by the lumbermen that if he wanted any piles he would have to take all timber just as it was cut, whether large or small. Haste being imperative, he had accepted, and said what could not be driven would have to be used for firewood.

Piles driven in frosty ground, where frost has to be cut out before driving, should have the holes made of sufficient size to give some latitude for straightening up, or they may be driven badly and be hard to spring into place, and may throw the bridge out of line in the spring when the frost goes out of the ground. One must be careful in standing near piles driven in frosty weather. I once saw a splinter 6 feet long split off by the blow of the hammer just graze a man's back and bury itself in the frozen ground, whence it could not be removed. If the contractor fails to properly spring in piles, cap-drift bolts may be sawed off and piles properly resprung.

Some engineers carry their penchant for piles so far as to order them driven in all cases. In some instances this order has been so strict that, especially on side-hill work, piles have been dug out. A foundation on mud sills would seem to be perfectly allowable, at the discretion of the assistant. I have seen cases where an iron shoe, cast with a wrought iron dowel, enabled piles to be driven where otherwise penetration was impossible.

Under a large wharf and warehouse at a seaport town many of the piles were weakened by teredo, or more frequently girdled by a small insect which eats into the pile, diminishing its diameter 1 inch or more per year, until between tides there is nothing left. No difficulty was experienced in driving 80-foot piles outside the warehouse, but inside, in order not to remove the roof, a low pile driver was used and 20-foot lengths were driven down, one on top of another, to the desired depth and braced to the sound piles remaining. With proper bracing this could have been extended later to all the remaining piles, and with proper connections the last 20-foot pieces driven could have been taken up eventually and replaced by new ones over the whole area. Of course, this was in a harbor. In a seaway not even iron screw piles are always able to stand the force of the waves.

There are many ways to protect piles from teredo and insects. At Bay St. Louis they are encircled with vitrified pipe filled in with sand or cement. I have seen piles covered with tar paper, over which thin strips of redwood were nailed, as the teredo does not readily attack this wood. Copper sheets are sometimes used, but they are very expensive. Piles with bark on are much less rapidly attacked than when stripped of bark. In using piles with bark on, where it was accidentally knocked off in places, there was applied a coating of tar mixed with Paris green. I have but little faith in the effective endurance of this preparation.

Piles are not usually driven much closer together than 3 feet centers, for when they are driven closer it is not probable that they will sustain much more, for the whole inclosed space then tends to sink as a solid mass.

On the drainage work here in New Orleans test piles were driven over the whole area of the site of the central electric power station, as also at the sites of the several pumping stations. The results were exhibited to the eye in the form of curves in which the abscissas represent the penetration of the point of the pile below the surface and the ordinates the number of blows of the hammer required to cause one foot of penetration. Test borings were also made at each site, in order to determine the nature of the material in which the piles should be bedded.

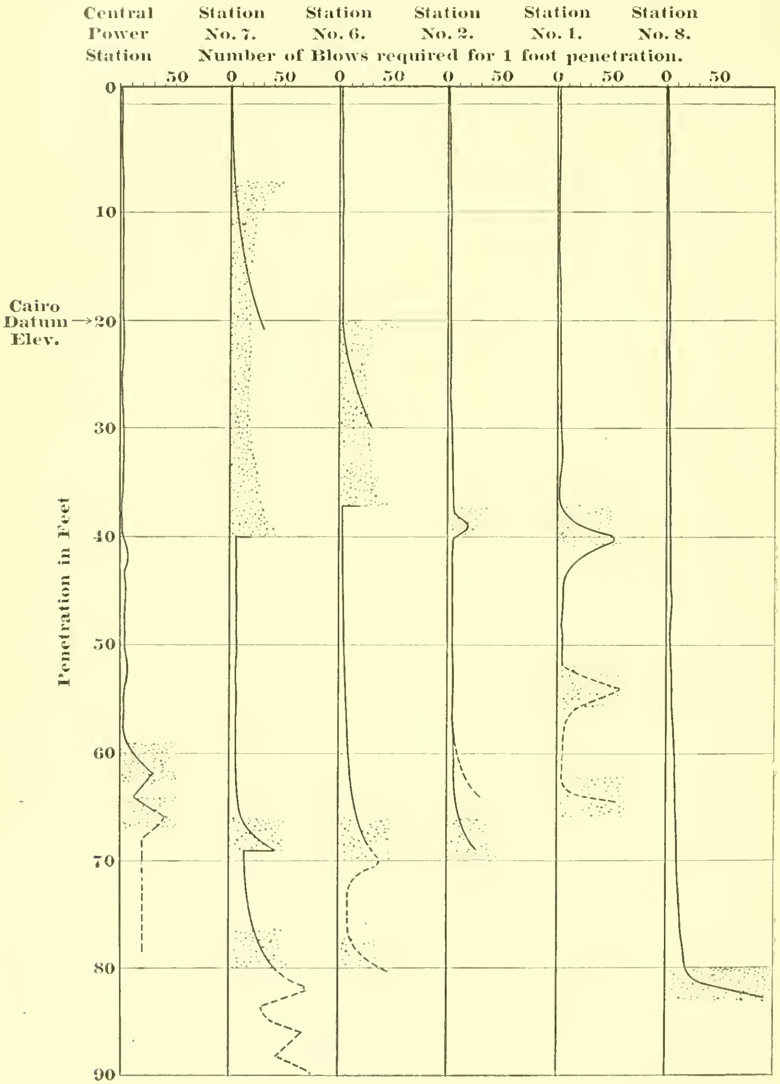
I have prepared a diagram showing a single curve of average results at each of the different sites. Curve No. 1 represents the results at the central station. Here the piles penetrated 35 feet under the static weight of the hammer alone. A satisfactory resistance was encountered in two strata of sand and shells at a depth of 65 to 70 feet below the surface, as shown, and piles were billed long enough to reach the second stratum should the first be penetrated too easily. Two thousand piles were driven, beginning at one side, and the driving did not become noticeably harder on account of the number of piles driven as the work proceeded, but the ground heaved up considerably and necessitated the raising of the plane of cribbing. It is sometimes better to drive from the center outward, but it is often easier and more economical to begin at one side. The ground being very full of old cypress stumps, many piles drove somewhat out of line. Cross-capping below or extra capping alongside was sometimes resorted to in such cases. The piles in the stack foundation were allowed to project 6 feet upward into the masonry, making it a much more stable structure than if set immediately on grillage.

At station No. 7 a sand stratum was met at 10 feet below the surface, giving great resistance. The first test pile was driven for a long time, but failed to pierce through. The second was helped by a small water jet, but it also failed to pierce. Then a larger jet was rigged up, and the lower side of the stratum was found to be at a depth of about 41 feet, showing a thickness of over 30 feet. This would have given a bed of sand of over 20 feet below the foundation of the building. It was not, however, deemed advisable to dispense with piles, as there would be such a head of water against the building on the lake side and the sand, although sea sand, was water bearing and might flow.

In driving the piles the jet was sunk with the pile only to the bottom of the sand stratum, where it was held, and this removed nearly all friction to that depth. Beyond this the piles drove through a second resisting stratum at 70 feet depth, and brought up witn good resistance on a third stratum at a depth of 80 feet. One test pile driven 90 feet indicated still another resistance at that depth. The jet was attached to the side of the pile, and the point seemed to have a slight tendency to follow the jet sidewise in going down.

At station No. 6 a sand stratum was encountered at a depth of about 22 feet. The test piles showed that this stratum could be penetrated by hard driving, but a jet was used later for economy and to secure more uniform and better results. Piles jetted gave

usually good resistance at a depth of 70 feet, as shown. During the excavation work it was seen that not all the test piles had



pierced the sand stratum, but those with knotty ends had broken off some distance from the point; and the new point thus formed reaching the sand, in some instances a second break had occurred. Some of these piles were entirely dug out, the points never having

reached cut-off when the record showed many feet below. Test pile No. 1 at station No. 7 was also dug out, and proved never to have reached cut-off. Some feet above the point was a mass of fiber, resembling worn out rope. This mass was as large as a barrel, and of about the same shape.

At station No. 2 a resistance was met at a depth of about 40 feet, which, however, was safely penetrated, the piles bringing up at 65 and 70 penetration with good resistance.

At station No. 1 the test piles showed resistances at depths of 40, 55 and 65 feet. The first stratum was penetrated with difficulty, the second in but one or two instances. Piles were intended to rest on the second stratum about 35 feet below cut-off. With hard driving, nearly all reached this stratum. In driving test piles the second day two of them refused to penetrate the first stratum, six hundred blows of the hammer seeming to have no effect. I had just read in an engineering paper that piles driven in sand to refusal, if allowed to rest, after dispersal of strains at the point, could be driven further down. It was decided to leave these two piles 20 feet above the ground. Redriven the next day, after about sixty blows to remove friction, they started and went down with unexpected ease. It seems that after the driver has stopped for any reason the piles usually start harder, but, once started, they go down at the previous rate. Piles rested over night are harder to start, but, once started, they also go on down as easily as on the day before. The same proves true of piles rested for a month or more. When an ordinary pile follower is put on the pile seems to go somewhat harder, but this may be due to the cushion formed by an imperfect joint. A broomed head forms a cushion, so as to give false results in calculating sustaining power of pile. The pile head should be cut off afresh and proper record taken.

At station No. 8, in Algiers proper, resistance was discovered at a depth of about 85 feet by the first test pile driven. Then two test piles drove to 130 feet with no bottom. These were 70-foot piles, doweled and followed by 60-foot piles. At one point there was a jump of from four blows per foot to two blows per foot; and although the difference was so very slight, it was still noticeable, and it was suspected that the followers had jumped off. Usually the follower will stand a great deal of driving before failing. Work was stopped and iron rings were sent for; head and point were strongly ringed and doweled. These piles brought up at 85 feet, practically at refusal, showing conclusively that previous results were false. Piles with large points drove harder and gave greater resistance, and sooner than those with slim points.

On the pole line between the central power station and stations Nos. 7 and 6 piles were driven for supporting the poles from Bayou St. John to station No. 6. The sand stratum encountered rose from 14 feet in depth at Bayou St. John to 10 feet at station No. 7, and fell to 22 feet at station No. 6, showing the highest point of the sea beach to be at station No. 7. It is lower toward the lake, and also toward the river. Large quantities of many varieties of sea shells in perfect preservation were found during the excavation for the foundations. These shells, where they were abundant, gave much greater resistance to the piles than the sand alone.

In driving piles for bridges over canals, throughout the first or upper drainage district, a sand stratum was encountered at a depth of about 40 feet which gave sufficient resistance. When this stratum is reached piles bring up almost as suddenly as if they had struck rock. With hard driving it can be pierced as at station No. 1. Piles were billed 40 feet long, and usually gave a little waste. This stratum extends also over the second drainage district on the river side of Metairie Ridge, and supports the piles of all the conduit work, as well as bridges over canals. In removing old piling, to allow the passage of the dredge at bridge sites, a hole is reamed out, into which is introduced a light pole to which two dynamite cartridges are attached. These are fired by electricity, and cut the piles off easily and with certainty.

The system of massing piles under heavy weights was preferred in foundations to that of spacing them uniformly over the whole area, even if the concrete base on strong grillage should act as a monolith. Some engineers prefer to drive all piles to a uniform resistance, decided upon beforehand, no matter at what depth it is encountered, but we drove to the greatest resistance we could get, depending on the average for good results. When foundations are large and act as a monolith, this would seem to be the better rule. Theoretically, if pile-driving over portions of a large foundation became harder, it would be economical to calculate on greater sustaining power and omit a portion of the piling.

The steam hammer, with its low fall and rapid blows, is much to be preferred to the drop hammer, which gives rest between blows and tends to mash the heads. The steam hammer was required on the drainage work, and those used weighed about 9000 pounds, the hammer proper weighing 4500 pounds. The drop measured $3\frac{1}{2}$ feet. It was calculated not to make any pile bear more than 10 tons, and a resistance more than sufficient to support that amount safely was always obtained from average results.

TESTS OF CONCRETE FOR ELASTIC PROPERTIES AND ULTIMATE STRENGTH.

By W. H. Henby.

[Read before the Engineers' Club of St. Louis, June 13, 1900.*]

The use of concrete for a building material is increasing very rapidly; its strength and durability, combined with ease of handling in construction, and cheapness make it a very satisfactory material for use in construction where it has been the practice to use stone or brick masonry.

Compared with its increasing popularity, and the great demand for hydraulic cement during the last few years, there is very little definite information in engineering literature upon its physical properties.

The standardization of the testing of cement, and the testing of a number of cubes and prisms for ultimate compressive strength and elastic deformation, in some of which tests data are given to show what is the most efficient mixture for the given class of materials under the existing conditions, represent the greater part of what has been done and is to be found in print upon this subject. The tests made have been for the determination of the compressive strength of concrete and its compressive modulus of elasticity, and, while these are the physical properties of most interest to users of concrete, some definite information upon the tensile strength and tensile modulus of elasticity may prove to be of more than merely theoretical interest.

For several months the writer has been engaged with Mr. E. C. Dicke, of the class of 1900, Washington University, in a laboratory investigation of the elastic properties and ultimate strength of stone and cinder concretes under both tensile and compressive stresses. These tests were made in the Washington University Testing Laboratory as thesis work.

It is the purpose of this paper to present the results of these tests and some conclusions derived from a consideration of them, and to consider briefly some of the factors entering into the mixing and placing of concrete which affect its efficiency.

In reviewing what has been done in this field of investigation a lack of uniformity of results is encountered, not only between the results of different investigators, but in the results coming from the same source. This lack of uniformity may arise in part from the range in strength of the component parts, and, in any investi-

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gation, should be determined so far as is possible and weighted when evaluating results.

Where stone, crushed to stated sizes, as in this investigation, is a component part of the mix of concrete, incipient fractures in the pieces of stone may greatly reduce the tensile strength of a test-specimen. Such a fracture not only reduces the area of cross-section by the component of the fracture at right angles to that axis of the test-specimen in whose direction the stress is applied, but, by introducing an element of weakness in one part, causes the section to be unsymmetrical and the specimen to fail by a combined tensile and cross-breaking stress. The fact that in this investigation the stone concrete failed at a lower tensile stress than the ultimate tensile stress of the mortar used in making the concrete, and that the stones in the plane of rupture were pulled in two in that plane, shows the stone to be the element of weakness in the concrete when it is subjected to tensile stress.

Besides the range of strength of the component parts, the other principal factors which may cause a difference in the physical properties of any given mix of concrete are: The much-mooted question of consistency; thoroughness of mixing; the compacting of the concrete in place, and the treatment of the test-specimen while it is seasoning. In regard to consistency, the conclusion derived from a careful consideration of the numerous tests made is that the greatest strength is developed when the mix is damp enough for a small amount of moisture to be flushed to the surface under heavy ramming. This consistency is usually designated "dry." A less amount of water than enough to effect this consistency does not insure a coating of all the coarser components with the cement and a weaker product results. A greater amount of water gives the mix sufficient plasticity to prevent the effecting of the desired density, and the broken section shows voids of considerable size and aggregate volume proportional to the excess of water used. From the tests it appears that the decrease in strength due to an excess of water is rather more than proportional to that excess.

The tests show that, other conditions being equal, any increase in density effected by compacting in place by ramming increases very materially both the ultimate compressive and the tensile strength.

In regard to treatment: The specimen made of the right consistency to give greatest strength and allowed to set in the dry air of the laboratory without the protection of damp cloths during the first forty-eight hours had a less ultimate strength and somewhat

TABLE I.

Showing the Modulus of Elasticity and Ultimate Tensile Strength of Various Mixtures of Stone-Concrete, Mortar and Cement; also the Effect of Density, Consistency and Treatment on the Strength.

No. of Test.	Marks	Age in Days.	Kind of Test.	Composition: Parts of Cement	Parts of Sand	Parts of Stone	Brand of Cement	Size of Broken Stone in In.	Treatment	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity	Ult. Str. in Lbs. per Sq. in.	Consistency	Remarks.
8		7	Tension	1	2	4	Lehigh	1½	Air dry		2,000,000	130	Dry	
10		18	"	1	2	4	Medusa	1½	"		2,286,000	75	Excess	Not well compacted.
16		30	"	1	2	4	Lehigh	1½	"	142	2,882,000	198	Dry	
17		30	"	1	2	4	"	1½	"	148	4,727,000	227	"	Very dense specimen.
18		30	"	1	2	4	"	1½	"	142	2,269,000	191	Plastic	
35	64	55	"	1	2	4	"	1½	"	147	4,543,000	149	"	Very solid section.
36	31	90	"	1	2	4	Medusa	1½	"	147	3,500,000	125	Excess	
65	55	96	"	1	2	4	Lehigh	1½	"	146	3,992,000	190	Plastic	
66	56	96	"	1	2	4	"	1½	Air	147	4,760,000	226	"	All stone in section broken.
72	84	8	"	1	2	4	Atlas	1½	"	157	3,720,000	213	"	
67	57	100	"	1	2	4	Lehigh	1½	Air dry	147	5,075,000	209	"	Well-made specimen.
18	1	30	"	1	2	4	Atlas	2	Air	148	3,306,000	192	"	
165	24	120	"	1	2	4	Medusa	1½	Air dry	143	3,473,000	136	Excess	Large voids in section.
166	25	120	"	1	2	4	"	1½	"	144		89	"	" " " "
220	21	90	Compression	1	2	4	Atlas	2	"	140	4,421,000	1,243	Dry	Adhesion poor.
221	24	90	"	1	2	4	"	2	"	144	5,792,000	982	"	" "
222	82	30	Tension	1	2	4	"	1½	Air	153	3,750,000	223	Plastic	Clean break.
223	83	30	"	1	2	4	"	1½	"	150	3,600,000	241	"	
224	85	30	"	1	2	4	"	1½	Water	158	3,550,000	279	"	Very solid section.
225	36	30	Compression	1	2	4	"	1½	Air	160	7,171,000	3,020	"	
226	37	30	"	1	2	4	"	1½	Water	152½	4,025,000	2,610	"	Slightly defective.

TABLE I.—Continued.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Parts of Sand.	Parts of Stone.	Brand of Cement.	Size of Broken Stone in In.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. In.	Consistency.	Remarks.
227	18	90	Tension	1	2	4	Atlas	2	Air dry	147		58	Very dry	Water absorbed by stone.
283	11	65	"	1	2	4	"	2	Air	144	3,810,000	143	Plastic	Failed in head.
284	12	65	"	1	2	4	"	2	"	149	3,724,000	102	"	Voids due to excess of water.
286	58	65	"	1	2	4	"	2	Water	150	5,440,000	82	"	" " " " " "
295	8	64	"	1	2	4	"	2	Air	151	7,744,000	252	Dry	Failed in plane of micrometer screws.
315	109	30	"	1	2	4	"	2	"	149	8,360,000	183	"	Failed in shoulder.
316	110	30	"	1	2	4	"	2	"	148½	7,280,000	214	"	" " "
3		14	"	1	2	5	Medusa	1½	Air dry	139	2,000,000	85	Plastic	Not well rammed.
5		18	"	1	2	5	"	1½	"		2,106,000	120	"	Same mix as No. 3.
22		60	"	1	2	5	Atlas	1½	"	144	1,857,000	111	Very dry	Adhesion to stone poor.
25		60	"	1	2	5	"	1½	"	146	3,253,000	128	Dry	
26		60	"	1	2	5	"	1½	"	146	3,023,000	189	"	
30		90	"	1	2	5	Medusa	1½	"	140	3,776,000	142	"	
76	38	9	Compression	1	2	5	Atlas	1½	Air	152	4,930,000	423	Plastic	
78	89	7	Tension	1	2	5	"	1½	"	152	3,968,000	147	"	Voids in broken section due to excess of water.
80	25		Compression	1	2	5	"	2	Air dry	146	3,927,000	726	Very dry	Rammed in mold transversely.
106	14	90	Tension	1	2	5	"	1½	"	144	3,696,000	129	"	
107	15	90	"	1	2	5	"	1½	"	144	3,896,000	93	"	
236	87	30	"	1	2	5	"	1½	Air	145	4,532,000	165	Plastic	Failed in head.
237	88	30	"	1	2	5	"	1½	"	152	4,425,000	242	"	
241	90	30	"	1	2	5	"	1½	Water	155	5,000,000	239	"	Failed very close to the elastic limit.
248	39	32	Compression	1	2	5	"	1½	Air	151	5,055,000	2,097	"	Planes of fracture well defined.
249	40	32	"	1	2	5	"	1½	Water	154½	7,292,000	2,830	"	" " " " "
287	29	63	Tension	1	2	5	"	2	Air	146	4,980,000	154	Dry	Poor adhesion.
288	30	63	"	1	2	5	"	2	"	146	3,744,000	192	"	
91	94	7	"	1	3	6	"	1½	Water	154	3,828,000	115	Plastic	
96	21	30	"	1	3	6	"	2	Air	150	3,810,000	119	Dry	

TABLE I.—Continued.

No. of Test	Marks.	Age in Days.	Kind of Test	Composition: Parts of Cement	Composition: Parts of Sand	Composition: Parts of Stone.	Brand of Cement.	Size of Broken Stone in In.	Treatment.	Weight in Lbs per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs per Sq. In	Consistency	REMARKS
272	22	60	Compression	1	3	6	Atlas	2	Air		2,886,000	413	Very dry	Rammed in mold transversely.
242	91	30	Tension	1	3	6	"	1½	"	147		130	Plastic	
243	92	30	"	1	3	6	"	1½	"	147	2,427,000	104	"	All stone broken.
244	93	30	"	1	3	6	"	1½	"	148	2,440,000	128	"	Good section.
245	98	30	'	1	3	6	"	1½	"	144	4,496,000	93	"	High modulus elasticity not explained.
250	41	34	Compression	1	3	6	"	1½	"	143	5,104,000	1,310	"	
251	42	39	"	1	3	6	"	1½	"	146	7,520,000	1,733	"	Good test.
252	43	39	"	1	3	6	"	1½	Water	152	6,646,000	2,242	"	" "
253	44	38	"	1	4	8	"	1½	"	143	4,560,000	1,282	"	Well made specimen.
254	45	38	"	1	4	8	"	1½	Air	139	2,446,000	617	Excess	Voids in section due to excess of water.
255	46	38	"	1	4	8	"	1½	"	138	2,247,000	797	"	
270	99	30	Tension	1	4	8	"	1½	"	143	3,553,000	71	Plastic	
271	100	30	"	1	4	8	"	1½	Water	149	6,108,000	125	Dry	
282	47	30	Compression	1	4	8	"	1½	"	145	4,397,000	1,346	Plastic	Good failure.
23		90	Tension	1	3		Medusa		Air dry	136	3,988,000	199	Dry	Failed in shoulder.
24		90	"	1	3		"		"	139	5,202,000	234	"	" " "
117	37	120	"	1	3		"		"	136	5,144,000	144	Very dry	
118	38	120	"	1	3		"		"	136	5,150,000	154	"	
235	53	95	"	1			"		Water	137	6,423,000	645	Plastic	Failed in head
291	4	90	Compression	1			"		"	136	6,578,000	5,280	"	Sudden failure.
292	7	90	"	1			"		Air	129	3,940,000	4,580	"	" "

TABLE II.

SHOWING THE VALUES OF THE MODULUS OF ELASTICITY AND ULTIMATE STRENGTH OF VARIOUS MIXTURES OF CINDER-CONCRETE, AND THE EFFECT OF SETTING IN AIR AND IN WATER.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Parts of Sand.	Parts of Cinder.	Brand of Cement.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. In.	Ult. Comp. Str. in Lbs. per Sq. In. on Cubes.	Remarks.
43	65	7	Tension.	1	2	4	Atlas	Air	118	1,854,000	46		
44	66	7	"	1	2	4	"	"	114	1,892,000			Not broken.
46	68	7	"	1	2	4	"	Water	122	1,826,000			" "
49	1	7	Compression	1	2	4	"	"	120	514,000			" "
50	2	7	"	1	2	4	"	Air	116	876,000			" "
48	3	7	"	1	2	4	"	"	111	945,000			" "
141	66	30	Tension	1	2	4	"	"	113	2,800,000	133	993	
149	68	30	"	1	2	4	"	Water	121	2,909,000	77	1,415	Solid section. No flaw apparent at point of rupture.
152	1	30	Compression	1	2	4	"	"	119	1,358,000	993		
153	2	30	"	1	2	4	"	Air	112	1,626,000	1,049		
154	3	30	"	1	2	4	"	"	106	1,399,000	976		
159	69	30	Tension	1	2	5	"	"	109	2,853,000	86	1,039	
155	72	30	"	1	2	5	"	"	107	2,329,000	86	1,054	
167	73	30	"	1	2	5	"	"	102	1,820,000	78	688	
171	74	30	"	1	2	5	"	Water	126	1,900,000	76	1,166	
174	75	30	"	1	2	5	"	Air	112	1,990,000	129	1,005	
189	27	30	Compression	1	2	5	"	"	109	1,772,000	941		
190	28	30	"	1	2	5	"	Water	114	1,021,000	705		
132	51	60	Tension	1	2	5	"	Air dry	117	2,413,000	97	882	
138	9	60	Compression	1	2	5	"	"	114	1,055,000	573		
139	15	60	"	1	2	5	"	"	116	1,783,000	847		
140	16	60	"	1	2	5	"	"	119	1,152,000	670		
163	7	30	"	1	2	5	"	Water	114	1,168,000	682		
2		12	Tension	1	2	5	Medusa	Air dry	113	1,428,000	60		Mix very dry.

TABLE II.—Continued.

No. of Test	Marks	Age in Days	Kind of Test	Composition: Parts of Cement	Composition: Parts of Sand	Composition: Parts of Cinder	Brand of Cement	Treatment	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity	Ult. Str. in Lbs. per Sq. In.	Ult. Comp. Str. in Lbs. per Sq. In. on Cubes	Remarks
195	49	60	Tension	1	3	6	Atlas	Air dry	110	1,274,000	58	699	Mix very dry
198	50	60	"	1	3	6	"	"	110	1,892,000	88	949	
203	47	60	"	1	3	6	"	"	107	2,215,000	62	677	Failed in head.
207	48	60	"	1	3	6	"	"	108	2,922,000	52		Failed in plane of micrometer screws.
216	10	60	Compression	1	3	6	"	"	107	917,000	734		
217	11	60	"	1	3	6	"	"	101	916,000	544		
186	79	30	Tension	1	3	6	"	Water	114	1,422,000	41	653	
192	30	30	Compression	1	3	6	"	Air		1,473,000	484		
193	31	30	"	1	3	6	"	"	107	1,447,000	511		
194	32	30	"	1	3	6	"	Water	118	751,000	500		
209	80	30	Tension	1	3	7	"	Air	102	1,034,000	30	409	
212	81	30	"	1	3½	7	"	"	104	937,000	31	510	
218	33	30	Compression	1	3½	7	"	"	100	533,000	405		

TABLE III.

Showing Tests in Tension on Concrete made from Limestone Screenings.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Composition. Parts of Screenings.	Brand of Cement.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. In.	Remarks.
33	35	90	Tension	1	5	Medusa	Air dry	124	2,538,000	252	
34	36	90	"	1	5	"	"	119	1,051,000	140	Not explained.
289	33	135	"	1	5	"	"	121	2,224,000	238	
290	34	135	"	1	5	"	"	122	1,508,000	151	
293	62	97	"	1	5	Atlas	"	116	3,095,000	150	Made very dry.
294	17	97	Compression	1	5	"	"	118	1,714,000	1,238	" " "

TABLE IV.

Showing Compression Tests on Concrete made from Limestone Screenings. Tests made on Wet and Dry Concrete.

No. of Test.	Marks.	Height in Inches.	Section, Inches.	Area in Square Inches.	Ultimate Strength in Lbs.	Ult. Str. in Lbs. per Sq. In. Tested Dry.	Ult. Str. in Lbs. per Sq. In. Tested Wet.
298	33	3.5	3.2 x 2.94	9.41	13,240	1,407	
299	33	3.5	3.45 x 2.94	10.14	13,800		1,360
300	34	3.5	3.76 x 2.9	10.9	16,110	1,478	
301	34	3.5	3.24 x 2.9	9.39	10,500		1,118
302	35	3.5	3.32 x 2.95	9.79	14,640	1,495	
303	35	3.5	3.42 x 2.95	10.09	12,540		1,243
304	36	3.5	3.02 x 2.82	8.51	14,100	1,657	
305	36	3.5	3.32 x 2.82	9.36	10,050		1,075
306	62	3.5	3.1 x 3.02	9.36	9,100	972	
307	62	3.5	2.74 x 3.02	8.27	5,700		689

TABLE V.—SHOWING EFFECT ON TENSILE STRENGTH AND ELASTICITY OF WETTING ON CINDER CONCRETE.

No. of Test	Marks	Age in Days	Composition. Parts of Cement	Parts of Sand.	Parts of Cinder	Brand of Cement.	Condition when Tested	Weight in Lbs. per Cu Ft	Modulus of Elasticity	Per Cent. of Absorption.	Ult. Str. in Lbs. per Sq. In.	REMARKS
274	101	33	1	3	6	Atlas	Wet	110	920,000	7.59	51	Piece of coal in broken section.
275	102	33	1	3	6	"	Dry	111	1,856,000		93	Failed in plane of extensometer screws.
276	103	33	1	3	6	"	Wet	108	850,000	8.31	46	" " " "
277	104	33	1	3	6	"	Dry	110	2,571,000		95	Failed at shoulder.
278	105	32	1	3	6	"	"	112	3,093,000		65	Defective from adhering to mold.
279	106	32	1	3	6	"	Wet	110		8.06	22	Poor section.
280	107	32	1	3	6	"	Dry	110	1,953,000		102	Good specimen.
281	108	32	1	3	6	"	Wet	117	915,000	6.77	64	Very dense.

TABLE VI.—SHOWING EFFECT OF MOISTURE ON COMPRESSIVE STRENGTH OF CINDER-CONCRETE AND STRENGTH OF CONCRETE AFTER BEING DRIED.

No. of Test	Marks	Height of Specimen Inches.	Section. Inches.	Area in Square Inches	Ult. Str. in Lbs	Ult. Str. in Lbs. per Sq. In. when Tested Dry.	Ult. Str. in Lbs. per Sq. In. when Tested Wet	Ult. Str. in Lbs. per Sq. In. after being Dried Out
308	102	3.5	3.45 x 2.9	10.	9,000	900		
309	102	3.5	3.15 x 2.9	9.13	5,840		640	
310	104	3.5	2.88 x 2.95	8.5	6,100	718		
311	104	3.5	2.9 x 2.95	8.55	6,500		760	
312	105	3.5	3.2 x 2.99	9.57	7,580	792		
313	105	3.5	2.6 x 2.99	7.77	4,950		63.	
314	107	3.5	3.6 x 3	10.8	9,600	897		
315	107	3.5	2.97 x 3	8.91	6,110		686	
316	101	3.5	3.25 x 2.88	9.35	7,680		821	
317	101	3.5	3.8 x 2.88	10.94	11,090			1,014
318	103	3.5	3.92 x 2.91	11.41	9,380		822	
319	103	3.5	3.45 x 2.91	10.04	11,380			1,134
320	106	3.5	3.87 x 3.01	11.65	9,300		798	
321	106	3.5	4.08 x 3.01	12.28	10,790			879
322	108	3.5	3.67 x 2.96	10.86	7,730		712	
323	108	3.5	3.93 x 2.96	11.63	11,075			1,004

* Defective

lower modulus of elasticity than the specimen protected from too rapid drying out for forty-eight hours. Stone concrete sets more rapidly in water than in air. Cinder concrete develops less strength when set in water than when set in air.

The tension specimens were made in cast iron moulds and had a sectional area of 10 square inches, being approximately $2\frac{7}{8}$ inches by $3\frac{1}{2}$ inches in cross-section, a length of reduced section of 14 inches, and an over-all length of 21 inches. Each specimen tested was measured for area of cross-section to the nearest hundredth of an inch.

The compression specimens were made in wooden molds with the same sectional area as the tension specimens and with a length of 11 inches, which is very nearly four times the least lateral dimension. The concrete was put into the molds in thin layers and each layer was well tamped to insure a uniform density.

Three brands of Portland cement were used in these tests,—viz, the Atlas, Lehigh and Medusa brands. The greater part of the test specimens were made with the Atlas brand of cement.

Unscreened Mississippi River sand, in the same condition in which it comes on the St. Louis market, was used for all tests.

The stone used was $1\frac{1}{2}$-inch and 2-inch limestone macadam, and this also was used for testing in the same condition in which it comes on the market. Voids in the 2-inch macadam measured by fine sand equal 43 per cent. Voids in $1\frac{1}{2}$-inch macadam measured by fine sand equal 46 per cent. Voids in sand used in measuring voids in macadam equal 34.3 per cent. Total voids to be filled in 2-inch macadam equal $57\frac{3}{4}$ per cent. Total voids to be filled in $1\frac{1}{2}$-inch macadam equal $61\frac{3}{4}$ per cent.

Cinders were used unscreened.

The stone and cinders were wet down in the pile to prevent their absorbing too much moisture from the mix. The sand and cement were thoroughly mixed dry and added to the stone or cinders in the mixing-pan.

All measurements were volumetric.

The cement was measured in such a way as would give very nearly, but not quite, the density of the original package and maintain a uniform density for all measurements.

The compression and tension tests were made on a Riehlé testing machine of 20,000 pounds capacity.

The deformations were measured by means of a dial extensometer having friction rollers. On this extensometer deformations of 0.0001 of an inch are read by means of a vernier needle. By using a good magnifying glass deformations of 0.00005 of an inch

were read very easily and quite accurately, as the platted curves prove. Elongations were measured in a gaged length of 10 inches. The gaged length in compression tests was 6 inches.

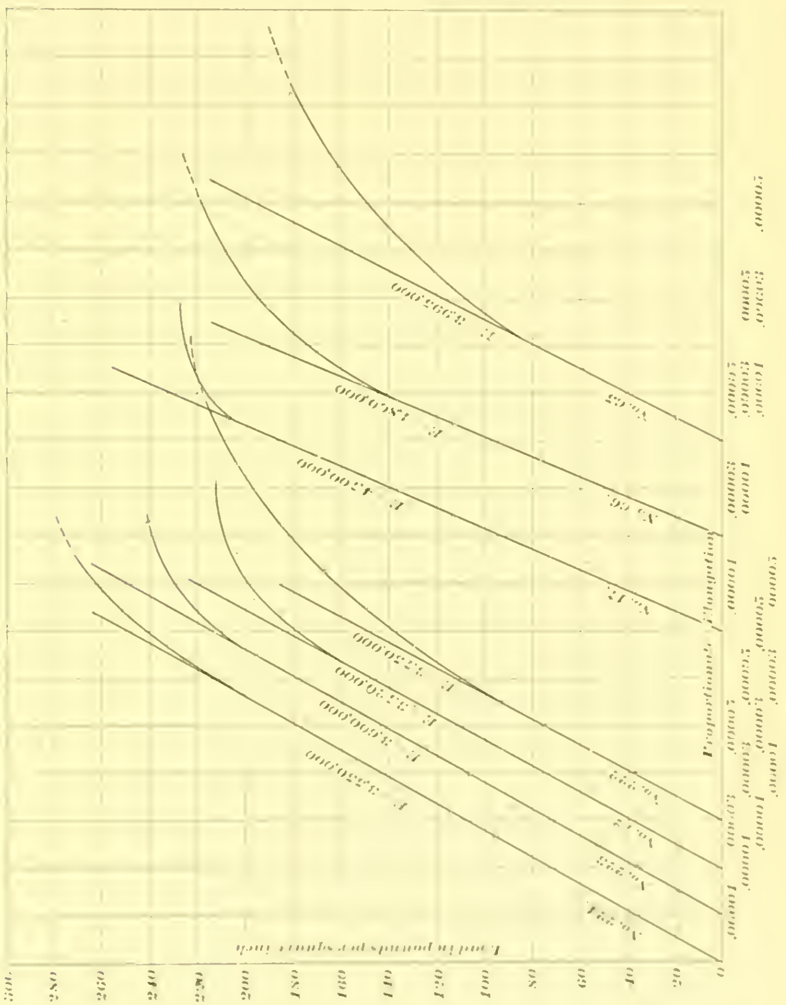

FIG. 1. SEVEN TENSION TESTS OF STONE CONCRETE.
Mix 1:2:4. E = Modulus of Elasticity.

It has been found that repeated loading to the elastic limit, and even somewhat beyond it, does not materially affect the modulus of elasticity. After the concrete is thirty days old the rate of gain of the modulus of elasticity is very slow.

By so proportioning the component parts that the voids in each component part were filled with a small excess for safety by the component part of next smaller size, and by using no more

water in mixing than just enough to bring the mix to the proper consistency, the greatest strength and the highest values of the modulus of elasticity were obtained for the given class of materials.

The failure of specimens made to develop the maximum strength for the materials used was in planes in which all stones were broken across in the plane; this is true of both compression and tension tests. When the pieces of concrete are broken with

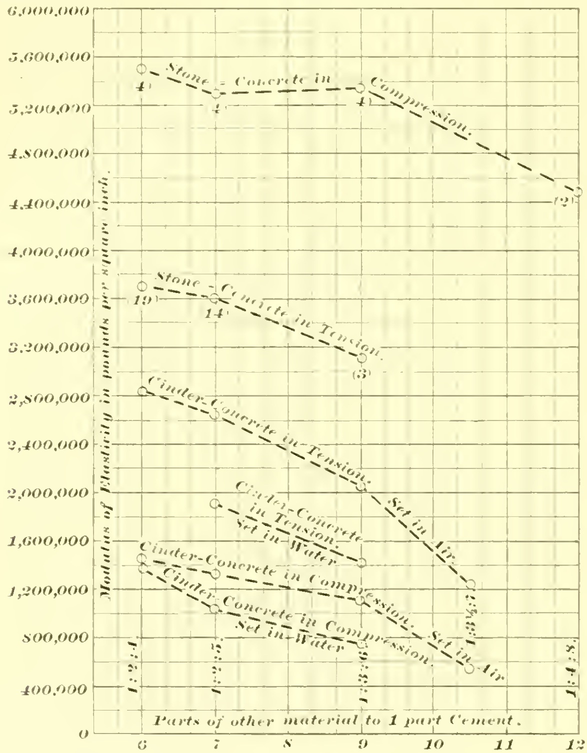

FIG. 2. MODULUS OF ELASTICITY FOR VARIOUS MIXTURES OF STONE AND CINDER CONCRETE IN TENSION AND COMPRESSION.

a hammer the planes of rupture go through stone and mortar alike, showing the mortar to be of equal strength with the limestone.

Numerous tests of different mixtures of cinder concrete have been made. Compression and tension test specimens were made from each mix to insure comparable results. At the time of testing each specimen was measured and weighed to determine the specific density, and in making comparisons between tension and compression tests only those tests having approximately the same density are taken into consideration.

Cinder Concrete, Wet and Dry. Table V shows the ratio of the ultimate tensile strength and modulus of elasticity between wet and dry cinder concrete of mixture with 1 cement, 3 sand, 6 cinders. The eight specimens were made in two mixes of four each; specimens marked 101, 102, 103 and 104 being of the same mix. All were set under damp cloths for forty-eight hours and then in dry air for a period of twenty-eight days, at the end of which

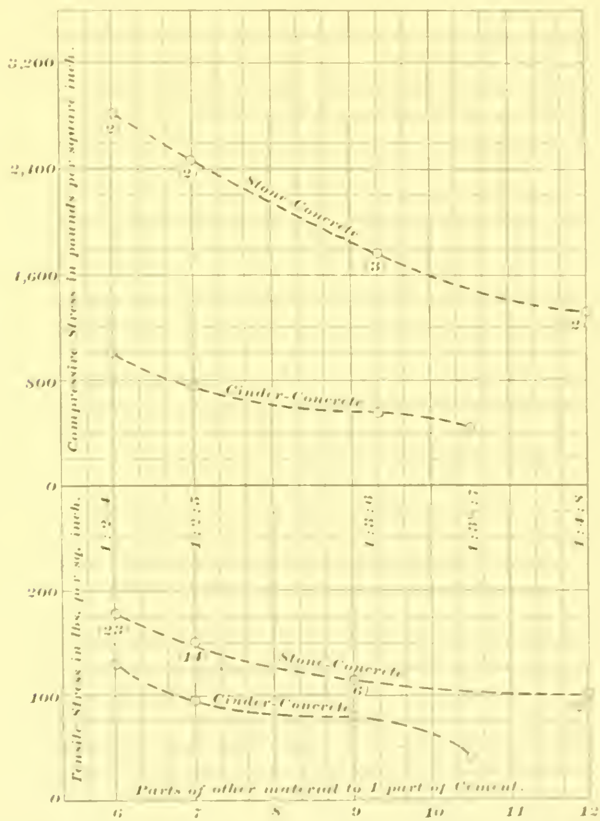

FIG. 3. STRENGTH OF STONE AND CINDER CONCRETE WHEN A MONTH OLD.

time two of each batch of four were put in water for a further period of three days, at the end of which time all were tested to rupture. The average tensile strength of the four tested dry was 89 pounds per square inch, while the average tensile strength of the four tested wet was 46 pounds per square inch. The average tensile modulus of elasticity of those tested dry was $2\frac{1}{2}$ times the average modulus of elasticity of those tested wet.

Table VI shows the ratio between the ultimate compressive strength of wet and dry cinder concrete. From each of the tension specimens, the results of tension tests of which are given in

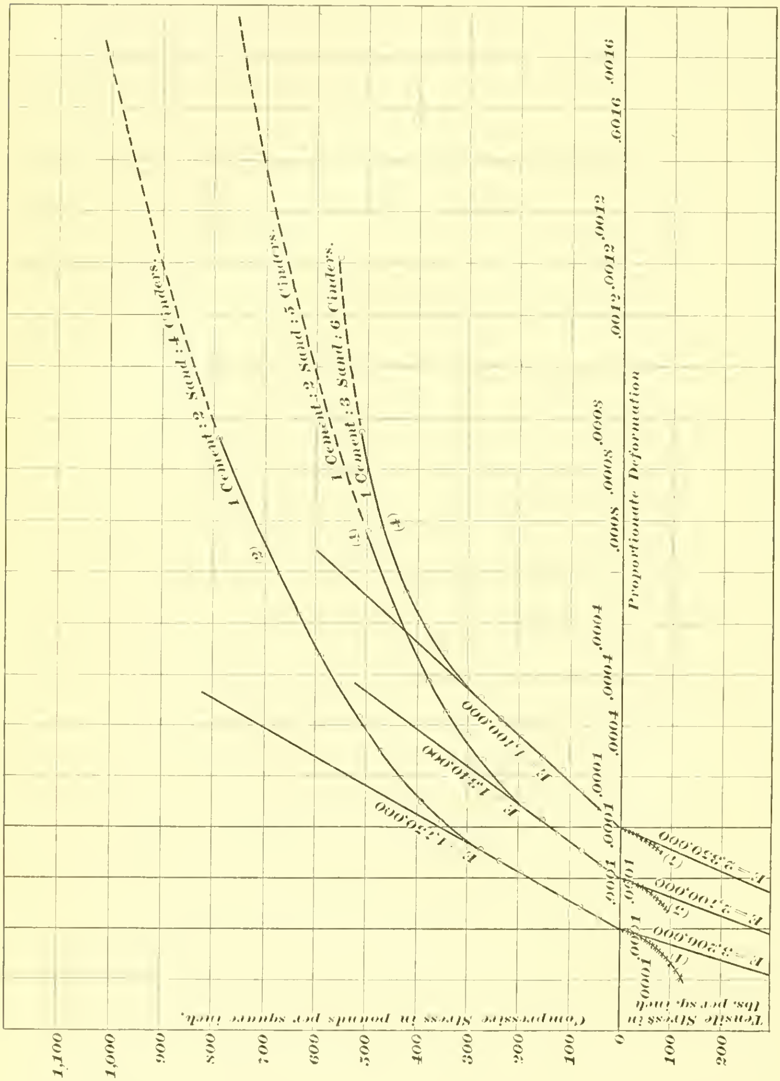

FIG. 4. AVERAGE CURVES OF COMPRESSION AND TENSION TESTS OF CINDER CONCRETE WHICH ARE COMPARABLE WITH CINDER CONCRETE BEAMS TESTED.

E = Modulus of Elasticity.

Table V, two compression specimens, approximating cubes, were taken. One of each of these two compression specimens was immediately tested for ultimate compressive strength. Of the other eight specimens, the four which were dry were put into the water bath for forty-eight hours and then tested wet, while the four wet

cubes were dried in a temperature of 125° F. for forty-eight hours and then tested dry. In all these tests the load was applied slowly. This table shows this concrete to have been one-third stronger, under compressive stress, when dry than when wet.

A series of tests on concrete of 1 cement, 5 limestone screenings showed the concrete to be 28 per cent. stronger when dry than when wet.

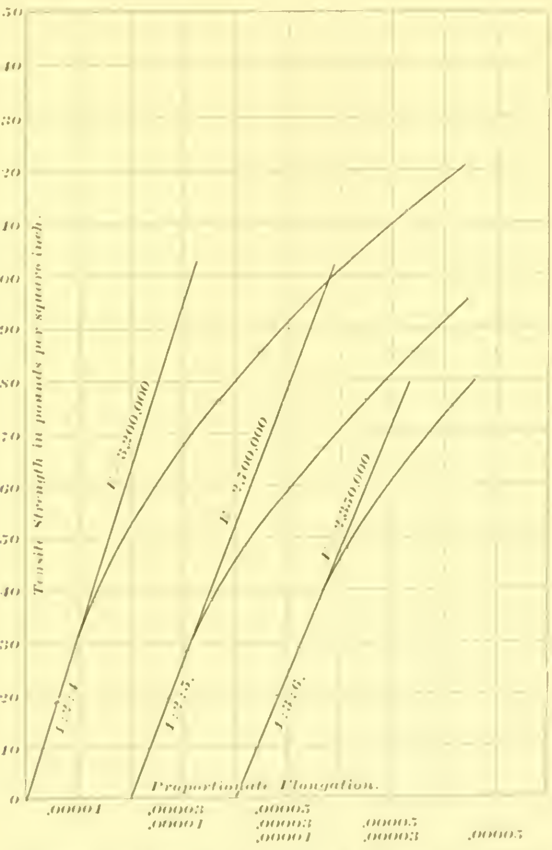

FIG. 5. AVERAGE TENSION CURVES OF CINDER CONCRETE SHOWN TO A SMALLER SCALE IN FIG. 4.

E = Modulus of Elasticity

Fig. 1 presents graphically the tests of seven stone concrete specimens in tension. The composition of each of these test specimens was 1 cement, 2 sand, 4 broken stone (1½-inch limestone macadam). Nos. 72, 222, 223 and 224 were made from the same mix. No. 72 was tested to rupture at seven days old. Nos. 222, 223 and 224 were loaded to 120 pounds per square inch at

seven days old, and tested to rupture at thirty days old with loadings and deflections as shown in the figure. The four were set under damp cloths for forty-eight hours, and then in dry air until tested, with the exception of No. 224, which was set in water. The tests shown in the figure are representative tests of stone concrete in tension.

Fig. 2 presents, graphically, the average values of the modulus of elasticity given in Tables I and II. In attaining these averages the values obtained from the tests of specimens whose broken sections showed the specimen to be defective were not included, so that these values may be taken to be fairly accurate for well-mixed and well-tamped "dry" concrete.

The numbers in parenthesis at each point on the curves indicate the number of tests averaged to obtain that point.

The average density of the stone concrete compression specimens was found to be greater than the average density of the tension specimens. This may account to a great extent for the much higher values of the compression modulus of elasticity of stone concrete.

The cinder concrete compression and tension specimens were of approximately the same density and were in all respects comparable. The higher values of the tension modulus of elasticity are characteristic, with hardly an exception, in a long series of experiments. This figure also shows the effect of setting cinder concrete in water.

In Fig. 3 is shown the strength of various mixtures of concrete. The compression tests were made on specimens whose height was four times the least lateral dimension.

In Fig. 4 average compression and tension curves of these mixtures of cinder concrete are shown in full. Only such tests as were comparable were used in making these average curves. This figure shows the ratio between the compression and tension moduli of elasticity, and the ratio between the ultimate compressive and tensile stresses.

In Fig. 5 the tension curves, shown to a small scale in Fig. 4, are shown to a much larger scale.

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WATER MEASUREMENTS IN CONNECTION WITH A TEST OF A CENTRIFUGAL PUMP AT JOURDAN AVENUE DRAINAGE STATION, NEW ORLEANS, LA.

BY W. M. WHITE, B.E., MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, October 8, 1900.*]

THE Jourdan avenue drainage station is situated at the intersection of the Jourdan avenue and Florida Walk canals. It drains the lower section of the city and discharges its water into an outfall canal, which empties into Bayou Bienvenue and thence into Lake Borgne. The station is equipped with two centrifugal pumps of the Guynne type, designed by the eminent hydraulician John Richards, of San Francisco, each being direct-connected to a 400 horse power triple-expansion condensing engine. Each pump has a capacity of 150 cubic feet per second when discharging against a head of 12 feet. The pumps are placed above the level of the discharge basin, the center line of the pumps being about 8 feet above the surface of the discharge canal; but the discharge pipes are submerged, so that the pumps get the benefit of the siphonic action of the water in flowing from the higher level of the pumps to the lower level of the discharge basin. Most of the pumping is done from a 2-foot to an 8-foot lift. The pumps are designed to run at 125 revolutions per minute at the 12-foot head.

OBJECT OF THE TEST.

This test was made to determine at what number of revolutions to run the pump for the different heads pumped against, in order to obtain the highest efficiency of the engine and pump com-

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bination. A comparison of the engine and pump horse power was made for different revolutions, while the head pumped against remained constant. That number of revolutions which gave the highest efficiency for the head was selected, and the pump is to be run at that number of revolutions when pumping against the corresponding head.

In making the test the suction basin was allowed to fill, in order to get a reading for the lowest head pumped against. The pump was then run at the highest possible number of revolutions, and readings of the engine and pump horse power were taken simultaneously. The pump was slowed down by equal decrements of ten revolutions until the lowest practical number of revolutions had been reached, taking the same readings of engine and pump

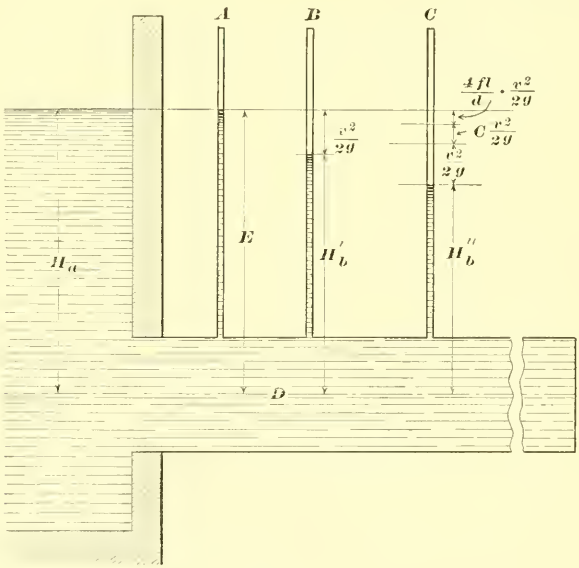

FIG. 1.

horse power at each decrement of revolutions. The reason for beginning at the highest number of revolutions was that the head pumped against might be kept constant. At the highest number of revolutions the velocity of water in the canals was greatest, consequently the velocity drop in the canals was greater than at the lower number of revolutions. During a reading the canals were lowered slightly, but when the pump was slowed down the water in the suction basin rose just enough to keep the head pumped against constant. After these readings were made the canals were

pumped down one foot and similar readings were taken, thus determining the number of revolutions giving the highest efficiency for each head.

THE ENGINE HORSE POWER.

The engine horse power was determined in the ordinary way, by using indicators and counting the number of revolutions. The indicators used were all Crosby instruments, and in good condition. They were not calibrated, as it was thought the percentage of error in them would be slight in comparison to the errors in some of the other observations.

THE PUMP HORSE POWER.

In determining the pump horse power the question of the velocity of the water through the pipes was a serious problem. In finding the velocity three methods were used, which were more or

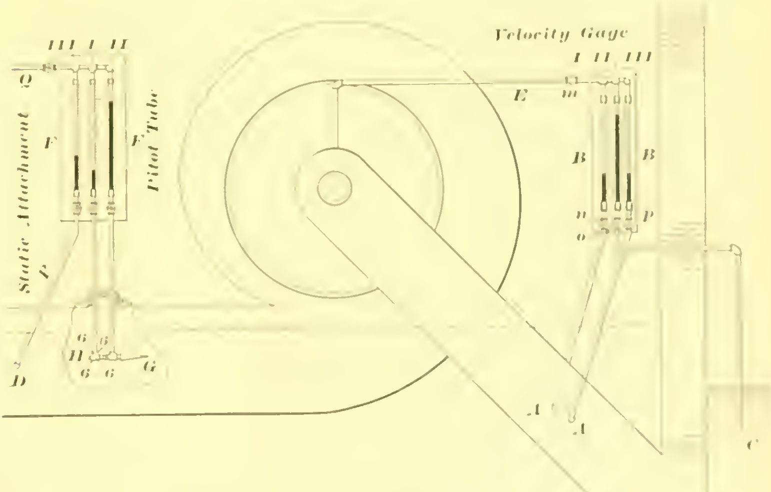

Fig. 2.

less dependent upon each other. On the first day's test a velocity gage, designed by the writer, was used on the suction side of the pump and a Pitot tube on the discharge side (see Fig. 2). The Pitot tube was found to give a higher velocity than existed, and on the second day of the test a static attachment was used in connection with it. By means of these methods, using them as checks against each other, the velocity in the pipes was determined within a small percentage of the true velocity. Knowing the velocity in feet per second, and the area in square feet of the cross-section of the discharge pipe, the number of cubic feet discharged per second was determined. Then the number of cubic feet discharged per

second, multiplied by the head discharged against (or the difference between the water levels of the suction and discharge basins) and by 62.3, gave the number of foot-pounds of water delivered per second, and this, divided by 550, gave the pump horse power.

THE VELOCITY GAGE.

The velocity gage is a device that suggested itself to the writer for determining the velocity of water in a pipe that takes its water from a basin. It embraces no new principles, but is an application of known hydraulic laws to local conditions. It depends for its action upon Bernouilli's thoerem, which says that "in steady flow without friction the sum of the velocity head, pressure head and potential head at any section of the pipe is a constant quantity, being equal to the sum of the corresponding heads at any other

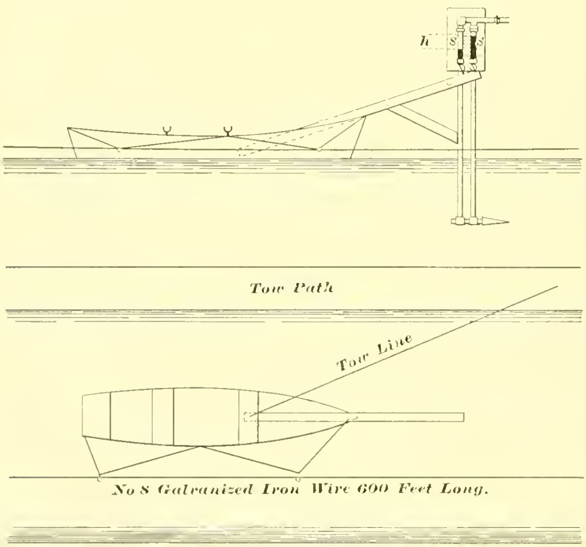

FIG. 3.

section." According to this law, the hydraulic pressure of flowing water against the interior of the pipe containing it is equal to the hydrostatic head (or the pressure which would exist if the water were at rest), less the head causing the velocity. If a vertical pipe A is connected with the pipe D, Fig. 1, leading from the basin, water will rise in the pipe A to a height E, which measures the pressure of the water against the interior of the pipe D at the foot of pipe A. If the pipe D is closed beyond A, the hydraulic pressure E will be equal to the hydrostatic pressure H in the basin; but if water flows through the pipe D the pressure at A must be less than

H_a, otherwise there would be no tendency for the water to move. Suppose that the hydraulic pressure in the pipe D was J, measured in feet of water, then K ($= H - J$) is the difference of pressure between the basin and the pipe D, expressed in feet of water, and is the pressure tending to set the water in motion from the basin to pipe B, or is the velocity head or the pressure which gives it the velocity of flow.

From Bernouilli's theorem we have, neglecting friction:

$$H_a + H_b + \frac{v^2}{2g} = H_a^1 + H_b^1 + \frac{v^{12}}{2g}$$

Where H_a, H_a^1 = hydrostatic head at two points respectively.

H_b, H_b^1 = hydraulic head at two points respectively.

$\frac{v^2}{2g}$ $\frac{v^{12}}{2g}$ = velocity head at two points respectively.

Substituting the values in Fig. 1, we have:

$$H_a + 0 + 0 = 0 + H_b + \frac{v^{12}}{2g}$$

$$H_a = H_b^1 + \frac{v^{12}}{2g}$$

To make the foregoing equation complete it is necessary to take into consideration the loss of head due to the abrupt opening from the basin into the pipe, and that due to the friction in the pipe. Both of these quantities are functions of the velocity, and are determined by constants multiplied into the velocity head. The loss of head due to friction in the pipe is given by

$$\frac{4\,f\,l}{d}\,\frac{v^{12}}{2g}$$

Where f is the coefficient of friction, l is the distance from the opening of the pipe to the point where the hydraulic pressure is measured, and d is the diameter of the pipe. The loss of head due to the abrupt entrance is $c\,\frac{v^2}{2g}$, and the completed equation becomes:

$$H_a = H_b'' + \frac{v^2}{2g} + c\,\frac{v^2}{2g} + \frac{4\,f\,l}{d}\,\frac{v^2}{2g}$$

Solving for V,

$$V^2 = \frac{1}{1 + c + \frac{4\,f\,l}{d}}\,2g\left(H_a - H_b''\right)$$

and representing $H_a - H_b''$ by h

$$\text{and } \frac{1}{1 + c + \frac{4\,f\,l}{d}} \text{ by } \phi^2$$

the equation can be written:

$$V^2 = \phi^2\,2gh$$

$$V = \phi\sqrt{2gh}$$

In calculating the value of ϕ, the term representing the loss of head due to friction may be neglected, since the hydraulic head is measured close to the mouth of the pipe. (See Fig. 1.)

The value of c is usually given as 0.5. Substituting these values:

$$\phi^2 = \frac{1}{1 + 0.5 + 0} = \frac{2}{3}$$

$$\phi = \sqrt{\tfrac{2}{3}} = 0.815$$

In using the velocity gage, the value of ϕ would have to be determined by calibration, as the value of c depends upon the opening into the suction basin.

Supposing a velocity of 5 feet per second in the pipe, we have:

$$V = 0.815 \sqrt{2gh}.$$

$$5 = 0.815 \sqrt{2gh}.$$

$$h = 0.59 \text{ foot.}$$

This gives a difference ($H_a - H_b''$) of 0.59 of one foot, which can be read without difficulty.

Suppose V = 6 feet per second, then $6 = 0.815 \sqrt{2gh}$. $h = 0.843$. This gives a difference of reading $H_a - H_b''$ of 0.02 of a foot for each increment or decrement of one inch velocity per second between 5 feet and 6 feet flow per second. The greater the velocity the more accurate the reading, the accuracy of the reading increasing as the square of the velocity.

PLACING THE VELOCITY GAGE.

At the Jourdan avenue pump two velocity gages had to be used, as there are two suction pipes.

In the suction pipes of the pump at A, A, Fig. 2, holes were drilled and tapped for ¼-inch gas pipes, and the ends of these pipes were not allowed to protrude into the interior of the suction pipes, and care was taken to remove all burrs from the inside of the pipe. Quarter-inch gas pipes were led from these holes to the scale BB, which was placed on the station wall. From experiments that have been made by Clemens Herschel, the tapping of the pipe in one place seems to be as good an arrangement as a piezometer for giving the hydraulic pressure. A third ¼-inch gas pipe was led from a still part of the suction basin C. The three pipes terminated in three ¼-inch glass tubes, I, II and III, which were fastened vertically on the scale BB. The tops of the tubes were joined to the same exhaust pipe E. The scale, BB, is 6 feet long, and graduated to 0.02 of a foot. It is placed behind the glass tubes, so that the three water levels are read on the same scale.

The exhaust pipe E, from the top of the tubes, was led back to the highest point of the suction pipe, and the scale BB was placed at such level as would bring the water levels on the scale; m, n, o and p are ¼-inch valves used to control the fluctuations in the water

columns, so that accurate readings could be made on the scale. Tubes I and III lead from the suction pipes, while tube II leads from the suction basin. The reading II — I gives h in calculating the velocity in pipe No. 1, while the reading II — III gives the same value for pipe No. 2.

PITOT TUBE.

The Pitot tube is an instrument for converging velocity head into hydrostatic head and measuring the hydraulic head, the difference between the hydrostatic and hydraulic heads being the velocity head, or h in the formula $V = \sqrt{2gh}$. For convenience in reading these water levels a scheme somewhat similar to that of the velocity gage was used (see FF, Fig. 2). Here tube II is connected with the point G, and gives the hydrostatic head, while tube I is connected to the hydraulic or rear part of the tube. This part should have been designed so that the water in rushing past the holes 6, 6, 6 did not have any impelling or suction action, giving only the hydraulic head.

The Pitot tube used in the test is one belonging to Tulane University. The constant of the instrument was supposed to be unity. The Pitot tube was placed in the discharge pipe of the pump, and was so arranged that it could be raised or lowered in the pipe and the velocity of the different strata of the water determined. The pipe was kept sealed at all times, and a vacuum of about 2 inches of mercury was maintained at the top of the discharge pipe within the pumping station. During an observation at first five, and later nine, readings were taken in quick succession, the positions of the point ranging from 2 inches below the top of the pipe to 5 inches above the bottom. When nine readings were taken, five were observed while lowering the tube and four while bringing it up. An average of these readings was taken as the average velocity of an observation. Another method of getting the average velocity of flow was by imagining concentric rings in the discharge pipe, calculating the cubic feet discharged for each ring and working back to an average velocity. This result was found to agree, within 0.5 per cent., with the first method, and it was discarded in favor of the first method.

STATIC ATTACHMENT.

After the first day's test it was found that the readings of the Pitot tube were too high, as compared with those of the velocity gage. For instance, notice observation No. 1, Table No. I. The Pitot tube gives the average velocity 17.01 feet per second. The velocity gage gives the average velocity as 16.02 feet per second

TABLE I.

Number of Observation.	Number of Reading.	Pitot Tube Reading. Scale Reading. I.	Pitot Tube Reading. Scale Reading. II.	Difference II − I = h in $V = \sqrt{2gh}$.	Velocity $V = \sqrt{2gh}$.	Average Velocity.	Velocity Gage Reading (Simultaneous). Scale Reading. I.	Scale Reading. II.	Scale Reading. III.	Difference. h. II—I.	Difference. h¹. III—II.	Velocity in Pipe No. 1.	Velocity in Pipe No. 2.	Average Velocity.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0.9	5.8	4.9	17.69		0.58	5.14	0.72	4.56	4.42	17.05	16.75	
	2	0.9	5.8	4.9	17.69		0.55	5.1	0.72	4.55	4.38	17.03	16.72	
	3	1.1	6	4.9	17.69		0.5	5.08	0.68	4.58	4.4	17.1	16.73	
	4	1.1	6.15	5.05	17.98		0.57	5.16	0.72	4.59	4.44	17.11	16.81	
	5	1.2	6.3	5.1	18.5		0.57	5.12	0.72	4.55	4.4	17.03	16.73	
						17.91					Average	17.06	16.79	16.92

TABLE II.

Number of Observation.	Number of Reading.	Pitot Tube and Static Attachment Reading. Scale Reading. Rear I.	Scale Reading. Point II.	Scale Reading. St. At. III.	h. P. T. II − I.	h¹. St. At. II − III.	Velocity by Pitot Tube. $V = \sqrt{2gh}$.	Velocity by Static Att. $V = \sqrt{2gh}$.	Velocity Gage Reading (Taken Simultaneously). Scale Reading. I.	Scale Reading. II.	Scale Reading. III.	Difference. h. II − I.	Difference. h¹. II − III.	Velocity in Pipe No. 1.	Velocity in Pipe No. 2.	Average Velocity.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	1	0.5	4.04	1.32	3.54	2.72	15.04	13.14	0.42	4.7	2.3	4.28	2.4	16.54	12.38	
	2	0.52	4.06	1.52	3.54	2.54	15.04	12.7	0.43	4.64	2.3	4.21	2.44	16.4	12.48	
	3	0.7	4.34	1.68	3.64	2.66	15.25	13	0.43	4.7	2.31	4.27	2.39	16.53	12.36	
	4	0.8	4.52	1.82	3.72	2.7	15.42	13.1	0.43	4.76	2.3	4.33	2.46	16.6	12.51	
18	5	0.74	4.6	1.88	3.86	2.72	15.7	13.14	0.44	4.78	2.30	4.34	2.48	16.64	12.58	
	6	0.6	4.56	1.6	3.96	2.96	15.9	13.7	0.42	4.64	2.28	4.22	2.36	16.42	12.28	
	7	0.33	4.26	1.38	3.93	2.88	15.84	13.55	0.42	4.62	2.26	4.2	2.36	16.38	12.28	
	8	0.1	3.9	1.2	3.8	2.7	15.58	13.1	0.42	4.64	2.24	4.22	2.4	16.42	12.38	
	9	0.2	3.6	0.82	3.4	2.78	14.7	13.3	0.42	4.64	2.26	4.22	2.38	16.42	12.32	
						Average	15.38	13.2					Average	16.48	12.40	14.44

without the introduction of the constant ϕ, which would never be as great as unity, so that the true velocity must be less than 16.92 feet per second.

The point of the Pitot tube, G, Fig. 2, is made according to the Darcy principle, and is correctly designed to give the hydrostatic head. The hydraulic, or rear part H, of the tube, Fig. 2, is not made according to the Darcy principle, and the conclusion was reached that this part of the tube was responsible for the error in the reading. As this part of the tube is intended to give the hydraulic head of the pipe, it occurred to the writer to tap the pipe at D, and obtain the hydraulic head in this way. Accordingly, a hole was drilled at D and tapped for a ¼-inch gas pipe, care being taken, as before, not to have any burrs and not to allow the pipe to protrude into the discharge pipe. This pipe, P, terminated in a glass tube, III, on the Pitot tube scale, the top of the tube being connected with the common exhaust pipe Q. This gave three water levels on the scale. The tube III gives the hydraulic head by the static attachment, II the hydrostatic head and I the hydraulic head, as given by the Pitot tube. Column eight, observation No. 18, Table No. II, gives the velocity determined by the Pitot tube; column nine that determined by the static attachment, and column seventeen that determined by the velocity gage. By a comparison of the velocities it is seen that the Pitot tube reading is 15 per cent. higher, and the velocity gage 10 per cent. higher, than that of the static attachment. Taking the latter as correct, and from it calibrating the Pitot tube by dividing the reading of column nine by the reading of column eight, the constant K was found to be 0.856, and calibrating the velocity gage in the same way gave the constant $\phi = 0.88$. This agreed so closely with the theoretical value of the constant that the reading of the static attachment was taken as correct. As a further check, the Pitot tube was calibrated by hauling it in front of a rowboat.

CALIBRATION OF PITOT TUBE.

The Pitot tube was calibrated in the Jourdan avenue canal (see Fig. 3). The canal is blanked off at one end. It consequently has very little current, and offers exceptional advantages for a calibration of this kind. For a course a No. 8 galvanized iron wire was stretched 600 feet just above the surface of the water. A point was marked off on the wire 50 feet from each end. These were used as starting and stopping points, and left between them a clear measured course of 500 feet. The 50 feet on each end was used to get a start before crossing the line, and to check the head-

way after crossing the line. By means of cords attached at bow, amidships and at stern, a rowboat was fastened to awning pulleys running on the wire. The boat was hauled with a tow line by men running on the bank. The awning pulleys and wire held the boat in a straight course. The greatest tendency of the wire to pull to one side was at the center, but in no case did the boat swerve more than 24 inches. The Pitot tube was fastened by means of an outrigger 3 feet in front of the boat, and the point of the tube was submerged 2 feet below the surface of the water. Glass tubes,

TABLE III.

CALIBRATION OF PITOT TUBE.

Number of Observation.	Direction. D = Down.	Distance in Feet.	Time in Seconds.	Velocity in Feet per Second.	Average Scale Reading in Feet. I	Average Scale Reading in Feet. II	Difference II – I = h.	Velocity from $V = \sqrt{2gh}$.	$K = \frac{\text{True Vel.}}{\sqrt{2gh}}$.
1	Up	500	102.5	4.87	Experimental Reading.				
2	D	500	101.5	4.925	0.28	0.799	0.519	5.776	0.854
3	Up	500	102.8	4.876	0.1804	0.674	0.486	5.64	0.863
4	D	500	95.3	5.249	0.115	0.72	0.605	6.24	0.842
5	Up	500	81	6.175	0.545	1.304	0.759	6.985	0.884
6	D	500	145	3.45	0.735	1.008	0.273	4.195	0.823
7	Up	500	98.7	5.07	0.613	1.174	0.561	6.015	0.843
8	D	500	75.3	6.64	0.92	1.885	0.965	7.875	0.843
9	Up	500		Failed to Catch the Time					
10	D	500	73.4	6.815	0.874	1.923	1.049	8.23	0.83
11	Up	500	120	Tube Stopped Up.					
12	D	500	76.4	6.548	0.787	1.779	0.992	7.99	0.82
13	Up	500	77.3	6.465	0.813	1.703	0.89	7.57	0.855
14	D	500		The Boat-Hauler Fell.					
15	Up	500	76	6.58	0.78	1.708	0.928	7.725	0.852
16	D	500	74.5	6.715	0.684	1.656	0.972	7.91	0.85
17	Up	500	102.2	4.89	0.853	1.343	0.49	5.62	0.869
18	D	500	91.9	5.44	0.784	1.406	0.622	6.325	0.86
								Average K =	0.849

$V = K\sqrt{2gh} = 0.849\sqrt{2gh}$. For Pitot Tube.

S, S, with a graduated scale behind them, faced the boat. These tubes were terminations of the point and rear pipes of the Pitot tube. They were joined together at the top, and the air was exhausted until water rose in them and its level could be read on the scale. Two men were seated in the boat. One was timekeeper, and with a stop watch noted the time occupied in traversing the 500 feet course. The other read as rapidly as possible the water levels on the scale. An average of these readings was taken, the difference of the averages giving h in the equation $V = \sqrt{2gh}$.

In going over the course the boat was hauled with as uniform speed as possible. The velocity in feet per second ranged from 3.45 to 6.8. In order to eliminate errors due to any current in the canal, the boat was reversed after each observation, and a reading was taken in going back over the course. The readings 1, 3, 5, etc., Table III, were taken in traveling up the canal toward the river, while readings 2, 4, 6, etc., were taken in traveling down the canal toward the pumping station. The up readings gave a little higher value of K than the down readings, showing a slight current in the canal; but this error was eliminated when the two were averaged.

The distance in feet divided by the time in seconds gave the true velocity in feet per second. The reading of the tube II minus the reading of the tube I gave h in the formula $V = \sqrt{2gh}$. This gave the Pitot tube velocity. Dividing the true velocity by the calculated velocity ($V = \sqrt{2gh}$), the quotient gave the value of the constant K. The true velocity is $K\sqrt{2gh}$ for the Pitot tube readings.

An average of fourteen observations, Table III, gave the value of $K = 0.849$, a difference of 0.7 per cent. as compared with the calibration by the static attachment.

DISCUSSION OF RESULTS.

Table No. IV gives the results of the three measurements in tabulated form. Each observation from 1 to 13 is a mean of five, and each from 13 to 29 is the mean of nine readings. Columns one, two and three give the readings of the Pitot tube, static attachment and velocity gage respectively, as calculated from the formula $V = \sqrt{2gh}$, without the introduction of any constant. Column four is a calibration of the Pitot tube from the static attachment by dividing the readings in column two by the readings in column one. Certain readings were rejected because the discharge pipe was not full of water, and because air then gathered in the pipe leading to the scale, rendering the readings unreliable. Column five is the Pitot tube reading multiplied by 0.849. This would be the true velocity, and would give the cubic feet discharged if the discharge pipe were full at all times. At a slow velocity of revolutions air would gather in the discharge pipe, and it would be running only half full of water.

Column six is the calibration of the velocity gage by dividing the observations of column three by the corresponding observations of column five. Only those observations that were taken when the discharge pipe was running full are used in determining the value for the velocity gage readings. The average of fourteen observations gives the value of $\phi = 0.881$. Multiplying the readings of column three by 0.881, the true velocity is obtained, as shown in column seven, and these were the velocities used in finding the pump

horse power. The Pitot tube readings cannot be used in determining the true velocity, because if the pipe is not full the cross-section of the discharged water is a variable quantity and difficult to determine. The suction pipe is full at all times, so that the velocity gage readings are the only ones that can be used.

TABLE IV.

Number of Observation.	Velocity by Pitot Tube where $V = \sqrt{2gh}$.	Velocity by Static Attachment where $V = \sqrt{2gh}$.	Velocity by Velocity Gage where $V = \sqrt{2gh}$.	Calibration of Pitot Tube from Static Attach. $= \frac{\text{Column 2}}{\text{Column 1}}$.	Column 1 x 0.819 for P. T. Corrected $V = K\sqrt{2gh}$ $= 0.819\sqrt{2gh}$.	Calibration of Velocity Gage $= \frac{\text{Column 5}}{\text{Column 3}}$.	True Velocity = Column 3 x 0.881 $V = \phi\sqrt{2gh} =$ $0.881\sqrt{2gh}$.	Remarks.
	1	2	3	4	5	6	7	
1	17.91		16.92		15.20	0.898	14.9	
2	15.56		15.23		13.20	0.867	13.41	
3	13.15		12.92		11.17	0.863	11.38	
4	12.47		11.95		10.57	0.885	10.53	
5	11.52		8.54		9.77	A	7.52	
6	12.67		10.23		10.77	A	9.01	
7	13.47		12.68		11.42	A	11.15	
8	13.27		12.83		11.25	0.877	11.3	
9	12.14		11.54		10.3	0.892	10.18	
10	12.32		9.25		10.46	A	8.15	
11	11.55		8.25		9.8	A	7.26	
12	9.94		6.61		8.43	A	5.825	
13	15.63		15.27		13.28	0.87	13.44	
14	13.88		13.75		11.78	0.857	12.11	
15	12.03		11.71		10.2	0.871	10.31	
16	13.09		10.12		11.1	A	8.92	
17	11.85		8.41		10.07	A	7.405	
18	15.38	13.2	14.44	0.859	13.06	0.904	12.72	
19	13.2	12.06	13.49	B	11.2	A	11.88	
20	12.27	10.4	11.4	0.853	10.41	0.913	10.03	
21	11.87	10.41	8.81	B	10.08	A	7.76	
22			6.53			A	5.75	
23	15.19	13.36	14.91	0.88	12.89	0.863	13.13	
24	13.52	11.56	12.85	0.855	11.48	0.893	11.32	
25	11.31	9.74	10.85	B	9.6	A	9.56	
26			8.23			A	7.25	
27	12.77	12.01	12.43	B	10.82	A	10.95	
28	10.54	8.79	10.12	0.834	8.95	0.885	8.92	
29			8.36			A	7.36	
		Average K =		0.856	Av. ϕ =	0.881		

NOTE A—Discharge pipe not running full.
NOTE B—Air bubbles caught in Static Attachment tube and the reading is not reliable.

I am indebted to Professor W. B. Gregory, of Tulane University, for the loan of the Pitot tube used in the test, for many valuable suggestions and for his assistance in working up the results. I am also deeply indebted to Mr. Alfred Raymond, general manager of the Drainage Commission, for his assistance, interest and encouragement in the work.

PUMPING BY COMPRESSED AIR.

By Edward A. Rix, M.E.

[Read before the Technical Society of the Pacific Coast, August 3, 1900.*]

My object in reading this paper is not to enter into an elaborate description of the various methods of compressed air pumping, but rather to touch on points which seem to have been heretofore neglected by those who have written on the subject, to suggest some new methods, and, if possible, to encourage the builders of pumping machinery to design pumps specially adapted to the use of compressed air.

From the very beginning compressed air has been handicapped, in the matter of pumping, because it has been used with stock pumps designed in general for boiler feeding and tank purposes, and no particular regard has been paid to matters of cylinder proportions and to appropriate pressures. Compressed air users, in the same manner, have been obliged to utilize old steam motors of all kinds, the general supposition being that steam motors are equally adapted for the use of compressed air. I will plead guilty to having committed this error on many occasions, and the remarkably poor efficiencies which I have obtained have led me to investigate the matter and to become a firm advocate of the designing of special motors for compressed air machinery. Great attention is paid to designing motors for the use of steam, even to the very smallest detail, and yet compressed air, which is almost doubly as expensive as steam to produce, has been compelled to take any misfit for its use. It has been condemned right and left for lack of economy, and has had a difficult time to maintain its proper existence in the face of the results it has produced in many cases with motors which were designed for something entirely different.

Those who are informed on the subject are perfectly well aware that while steam and compressed air follow in general the laws of perfect gases, their phenomena are sufficiently dissimilar to forbid their use in the same motor, the general difference being that for similar terminal pressures the points of cut off are different. Air does not condense and it is therefore capable of indefinite multiple reheating.

There has been sufficient development made in the line of air compressors, and the attention of manufacturers should turn to the constructing of economical air motors. Among the first to inaugurate this reform should be the pump builders; for pumps, as

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ordinarily furnished for compressed air use, have the lowest economy of any compressed air machinery, not even excepting a rock drill.

It is not necessary to revolutionize shop methods nor to carry an expensive stock of specially designed pumps in order to accomplish the results desired. Merely pointing out to an intelligent customer the fact that his pocket will be vastly benefited by having a pump specially constructed for his work should be a great help at the moment, and as soon as it becomes generally known that great advantages are to be gained thereby many will abandon the old methods and the reform will be inaugurated.

In this paper I shall endeavor to point out some economical methods of pumping water by compressed air, and to suggest how others might be accomplished.

Let us consider generally the various methods used to lift water by compressed air, and to compare them in such a manner that those interested may better understand the subject, thus enabling them to improve upon these methods when occasion offers. To those who believe that compressed air occupies an economical as well as a useful field it is discouraging to see the various tables, rules and computations offered to the public for calculating the amount of air required to lift water, without a word of explanation that might temper the almost general conclusion that compressed air is a very expensive luxury. It would require a stout heart and a long purse to put in a compressed air pumping plant if the verdict of the various quantity tables were final. One consulting these authorities would inevitably conclude that the efficiencies were so low that only pressing utility would decide in favor of compressed air.

The percentage of efficiency credited to compressed air, in these tables, ranges from 15 per cent. to 30 per cent. No mention is made of possibilities beyond these numbers, and we are left but the one conclusion, that from 4 to 7 horse power must be furnished to the compressor in order to produce a net yield of one horse power in water pumped, and particularly is this discouraging when enterprising advocates of electricity keep emblazoned before us all that imposing array of efficiencies that seem to almost jostle the revered 100 per cent. from its pedestal. Moreover, all this is misleading, for in the proper use of compressed air in pumps we may obtain efficiencies that are more than satisfactory, that, in fact, are difficult to exceed in many instances, and, in this paper, I have tried to make it clear how to practically realize these results.

As an example of the information given by some of the cata-

logues published by builders of compressed air machinery, take an example of 100 gallons of water per minute pumped 200 feet high. What is the quantity of free air and the pressure required in direct acting pumps? Reference is made to Table I, containing extracts from three publications. One hundred gallons per minute, 200 feet high, requires 5 theoretical horse power. Comparing this with the table we find that the efficiencies range from 17 per cent. to 40 per cent. (?), the pressures 11 to 50 pounds, the quantities from 225 to 130 cubic feet of free air per minute and the cylinder ratio from 1 to 1 to 5 to 1. It will also be noted that the pressures required for the same cylinder ratios vary 150 per cent. The pressures given are all receiver pressures or pressures in the main air pipe, which fact is not mentioned, leaving one to draw the conclusion that, no matter what the pressure in the main is, it is only necessary to install a pump with large cylinder ratio and use low pressures.

TABLE I.

FOR 100 GALLONS PER MINUTE. 200 FEET HIGH.

	No. 1.				No. 2.				No. 3.			
Ratio of Air to Water Cylinder.	Quantity of Free Air.	Gage Pressure.	H. P.	Efficiency.	Quantity of Free Air.	Gage Pressure.	H. P.	Efficiency.	Quantity of Free Air.	Gage Pressure.	H. P.	Efficiency.
1-1	134	11	29	17%								
1.5-1	153	48.8	21	24								
1.75-1	169	36.6	19.5	25								
2-1	181	27.5	16.2	30	130	50	18.2	27%	170	50	23.8	21%
2.25-1	197	22	15	33								
2.5-1	206	17.6	13.5	37	137	40	16.4	30	178	40	21.5	23
3-1					145	33	15.2	33	180	33	19	26
3.5-1					152	29	15	33	185	29	18.5	27
4-1					158	25	13.5	37	205	25	17	28
5-1					176	20	12	41.5	225	20	14.7	34

In mining, compressed air is used for driving rock drills, for hoisting and for pumping, and the average pressures carried in the mains correspond very nearly to the steam pressures formerly used for the same work; 90 pounds gage, independent of altitude, seems to be the standard pressure. This being the case, these tables and pumping data should all be calculated from some such standard basis, with proper coefficients for variations from the standard pressure; and a table, giving the proper cylinder ratios for different heads, using the standard pressures as a basis, would, it seems to me, be more helpful to those who wish to consult tables for a guidance.

In this paper we shall assume 90 pounds to be the standard pressure carried in the mains, and that it takes 20 brake horse power to compress 100 cubic feet of free air to that pressure at sea level with a single stage machine. This is more than is called for by the catalogues, but observations from a great many compressors, of many makes, justify me in this statement, and pressures all along the line will follow the same rule.

There appear to be six general forms of compressed air pumps:

First. Displacement pumps for full pressure only.

Second. Displacement pumps, using expansion.

Third. Direct-acting pumps for full pressure only.

Fourth. Direct-acting pumps, using expansion.

Fifth. Air lift pumps, simple, and combined with displacement chambers.

Sixth. Pumps operated by an independent motor.

The notations employed will be gage pressures unless otherwise specified. Temperatures are expressed in Fahrenheit degrees. The altitude is at zero, that is to say, sea level, and the atmospheric pressure is rated at 15 pounds for the sake of convenience, and 1 foot-gallon, or the work of lifting 1 gallon of water (0.134 cubic feet) to a height of 1 foot, is the unit of work to be performed.

The first general system of pumps, as before classified,—viz, displacement pumps for full pressure only,—appears to be the simplest of all, and is the one which would naturally be first suggested to the mind.

If we have a closed vessel containing water having a discharge pipe, let us say 210 feet high, full of water, connected to its bottom, and we force air at 90 pounds pressure slowly into this vessel, the air will rise to the top of the vessel, and water will be discharged exactly equal in quantity to the amount of air forced in, and $90 \times 0.068 + 1$, or 7, will represent the number of cubic feet of free air required to raise each cubic foot of water. Inasmuch as practice will require a certain additional pressure to give a dynamic head, and there is a certain amount of pipe friction to overcome and some air absorbed by the water, the number 7, before stated, can properly be made 9 cubic feet of free air used to 1 cubic foot of water pumped; or, expressed in foot-gallons, 1 cubic foot of free air, compressed to 90 pounds, will perform $\frac{1}{9} \times \frac{210}{0.134} = 175$ foot-gallons. The 1 cubic foot of free air has received $\frac{1}{5}$ horse power, or 6600 foot-pounds of work expended upon it. One hundred and seventy-five

foot-gallons = 175 × 8.3 = 1452 foot-pounds, so that we have here an efficiency of practically 22 per cent., and it will be observed later on that this is better than most ordinary direct-acting pumps will do with cold air as ordinarily used.

The efficiency of this system may be increased 15 per cent. by compound compression; or, if the water to be pumped has a higher temperature than the air, as for instance, in the Comstock, where the water temperature is 120°, the absolute temperature would be 580° and the efficiency would then be $22 \times \frac{580}{520} = 24.5$ per cent., assuming, for this illustration, that the Comstock is at sea level. In this system of pumping the air may be likened to a flexible plunger having a square foot area and making one stroke per minute, and having an actual length of stroke equal to the number of cubic feet of compressed air furnished per minute, diminished by the absorption, leakage, clearance and equivalent quantity necessary to furnish dynamic head and friction, and increased or diminished by the ratio of absolute temperature of air and water. It would be proper to range the efficiency from 15 per cent. to 22 per cent. The chambers of this pump must be submerged, and this fact limits its usefulness. In a sump, or tank, in a mine, and for lifts within range of ordinary compressors, say up to 250 feet, the efficiency obtained will probably exceed that of the ordinary direct-acting pump.

One can readily see that this system exhausts its chambers into the atmosphere at full pressure and all the expansive work contained in the air is lost. A proper compounding of this system, however, will be suggested later on, which will utilize some of this expansion and increase the efficiency materially. Without reflecting, perhaps, engineers have generally discarded this system as too primitive and uneconomical; whereas, in fact, in many instances, it is cheaper by far to install and often would exceed the efficiency of a direct-acting pump.

For handling sewage, or material which would obstruct or destroy pump valves, its utility gives it a desirable place; but, over and beyond this, a well-constructed pump of this type has a right to be properly considered in comparison with ordinary direct-acting pumps.

In pumps of this type there are generally two chambers, so that while one is filling the other may discharge, and thus insure a steady delivery, but frequently single vessels are found adequate. Fig. 1 gives a general idea of this type of pump.

As may be imagined, the inlet and outlet of the compressed air in the original pumps of this class were controlled by floats,

which are unreliable, and which greatly limit the size and shape of the vessels, and the clearance was excessive. The modern type, however, has eliminated all of these uncertainties, and the Merrill Pneumatic Pump Company has an automatic and positive differential controlling valve, situated above the chambers, which are free from floats. Many are in use, and, being free from many of the complications which exist in ordinary pumps, may be classed alongside of ordinary direct-acting pumps where submersion is possible. There is no reason why lifts in two or more stages would not be entirely feasible with this pump.

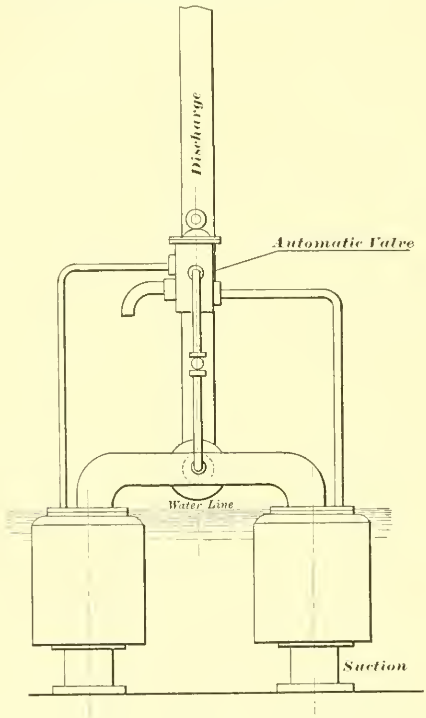

Fig. 1.* Merrill Type of Displacement Pump.

Class II consists of displacement pumps using more or less expansion. This class of pumps is best exemplified by the Harris system, owned and operated by the Pneumatic Engineering Company, of New York. This system is extremely interesting, simple and economical, and, I have no doubt, would in many cases prove to be the proper installation, especially in mines where a steady flow of water, at reasonable heads, is to be handled.

This system consists in displacing and elevating the water precisely as in Class I, with the difference that while in Class I

* For Figs. 2, 3 and 4, see pages 214, 215 and 216.

the air is immediately exhausted from the water vessels into the atmosphere and all its energy of expansion lost, the compressed air in the latter system, after displacing the water, is allowed to do work in expanding against the compressor piston, and thus, theoretically speaking, all its expansive energy is saved but practically the manufacturers admit that the losses in leakage and friction are about 15 per cent., a statement which deserves credence.

The action of the pump is as follows: There are two chambers placed within suction limit of the sump, or submerged, as desired. An air pipe leads from the compressor to the top of each chamber. There is a single water discharge connected with both chambers and a single suction. The system is so arranged that while one chamber is filling the other empties, and an automatic switch plays the important part of regulating the admittance and exit of the air. The system is a closed one and only leakage is replaced automatically.

Suppose one of the chambers filled with water. The air is then admitted at such pressure that the water is expelled and the air pipe and chamber are full of compressed air at the pressure of the water lift or slightly more. The other tank has, in the meantime, filled with water. At this point the automatic switch connects the air pipe of the empty chamber with the intake of the air cylinder, and the air pipe of the other chamber with the discharge of the compressor cylinder. It is evident that instantly the air in the first chamber will expand through the compressor and equalize the pressure in the empty air pipe of the second chamber and all clearances. This expansion is lost, but it amounts to but little. The compressor now transfers the air from the first chamber to the second, displacing the water in the second, and the air from the first chamber thus does work upon the air compressor piston in expanding from full pressure to zero. When zero pressure is reached in the first chamber, and if it is not submerged, the compressor continues to draw air from it until the water rises and fills it. At this point the first chamber is ready to be discharged, but if there has been leakage the second chamber has not received enough air to complete its discharge, and this is now supplied by a check valve in the intake pipe which is set to open at a suction pressure slightly above that necessary to draw the water into the chambers. If the chambers are submerged an ordinary check valve will automatically supply any deficiency in the air quantity. The second chamber being completely discharged, the automatic switch reverses and the cycle is complete. Of course

everything depends upon the reliability of the switch, which is placed on the air pipes near the compressor, where the engineer can see its operation and adjust it if necessary. It can be automatically operated in three ways.

First, by means of the suction which occurs in the intake pipe leading to the compressor, when the water is drawn above its outside level in one of the chambers.

TABLE II.

HARRIS' COMPOUND PRESSURE PUMP.

A. E. Chodzko.

Number of Double Strokes.	Pn Absolute Pressure per Sq. In. after Expansion.	$\frac{Po}{Pn}$	$\frac{Pn}{Po}$	$\left(\frac{Pn}{Po}\right)^{\frac{1}{r}}$	Effective Adiabatic Work of Compression and Delivery. Foot-Lbs.	Effective Isothermal Work of Expansion. Foot-Lbs.	Net Work of Compression and Delivery. Foot-Lbs.
1	88.9	1.18	0.847	0.89	25,704	19,580	6,124
2	73.5	1.39	0.719	0.79	24,768	15,991	8,777
3	64.1	1.63	0.614	0.71	23,509	12,937	10,572
4	54.4	1.92	0.521	0.628	22,824	10,339	12,485
5	46.2	2.27	0.44	0.557	21,270	8,142	13,128
6	39.2	2.66	0.376	0.497	19,960	6,267	13,693
7	33.3	3.14	0.318	0.441	18,360	4,687	13,673
8	28.3	3.7	0.27	0.39	16,517	3,347	13,170
9	24	4.36	0.23	0.349	15,480	2,195	13,083
10	20.4	5.13	0.195	0.31	13,738	1,231	12,507
11	17.3	6.05	0.166	0.28	12,845	401	12,444
12	14.68	7.13	0.14	0.246	11,088	—296	11,384
							141,040

Work of simple compression of 80 cu. ft. of free air to 90 lbs. gage at 6600, 528,000
Work of compound compression " " " " " 446,306

Efficiency of the system referred to compound is therefore, $\frac{446,306}{141,040} = 3.09$

and referred to simple is . . . . $\frac{528,000}{141,040} = 3.75$

Po initial absolute pressure in tank.
final " " in compressor = 90 lbs. g. = 1047 lbs. absolute.
Pn absolute pressure after the *n*th double stroke.
Pa " atmospheric pressure.

$$Pn = Po\left(\frac{V + a}{V + a + v}\right)^n$$

V volume of tank = 8 cu. ft.
a " pipe = 3.24 cu. ft.
v " compressor cylinder = 2 cu. ft.

$Pn = 104.7 \times 0.849\ ^n/\log.\ Pn = 2.019947 + n \times \bar{1}.928965$

Effective isothermal work of expansion.

$We = 267.87\ Pn - 4233.6$

Effective adiabatic work of compression.

$$We = \frac{v}{r\text{-}1}\left[r\left\{P1\left(\frac{Pn}{P1}\right)^{\frac{1}{r}} - Pa\right\} - \left(Pn - Pa\right)\right]$$

Theoretical actual work done in lifting water = 8 × 62.5 × 210 = 105,000 foot-lbs. allowing 85% mechanical efficiency. Real work done = 89,250 foot-lbs.

$$\frac{89,250}{141,000} = 63.3\%$$

Second, by a mechanism that will throw the switch at some assigned number of strokes of the compressor, the proper number being that which will empty one chamber and fill the other.

Third, by an electrically-controlled mechanism, the circuit being made and broken by a pressure gage on the intake of the compressor or by a float in one of the chambers.

In Figs. 3 and 4 we have diagrams and data supplied to the writer by the Pneumatic Engineering Company, which will be interesting to those who care to investigate this extremely interesting and economical method of pumping by compressed air.

Table II gives a problem of pumping under 90 pounds pressure, which shows in detail the change of work on the air compressor piston during the progress of changing the air from one water chamber to the other. It will be noted that the net work is even less than the full pressure work at 90 pounds pressure, thus showing that the compression work is practically eliminated, and that 90 pounds pressure can be transferred from one receiver to the other at less than one-third of the power required to fill a receiver at 90 pounds pressure. Consequently this system should be at least twice as economical as the regular displacement system. The disadvantage is that it requires an independent plant and a double set of air pipes. I have no hesitancy in placing the efficiency at from 60 per cent. to 70 per cent., and I consider it a very desirable system for mine station pumping.

DIRECT-ACTING PUMPS.

The ordinary direct-acting pump is the best known of all power pumps and is the typical example of a motor-driven displacement pump. Its efficiency suffers on account of its large clearance, its apparent inability to realize full stroke and the ill-advised selection of cylinder proportions. In general it is given a mechanical efficiency of 65 per cent. It is not a perfect displacement pump, because the valves are generally so arranged as to cut off just before the completion of the stroke, in order to exhaust the inertia of the moving parts by the time the stroke is finished, and this gives a slight expansion in the cylinder, but this expansion may be neglected in general and the pump put in the displacement class.

If a pump uses full pressure only, it is evident that the more full pressure its compressor diagram shows, the greater will be the efficiency of the system. The lower the air pressure the less is the compression work and the greater the proportion of full pressure work; consequently the lower the pressure the more efficient

is the system. This really refers to the compressor and not to the pump, for the pump works the same whether it receives air at 10 pounds pressure from the compressor or whether the air has been expanded from a receiver having a higher pressure, provided the temperatures are constant.

If, then, we look for the best efficiency from direct-acting pumps, we must put in an independent compressed air system and

TABLE III.

Press. of Air.	Volume. Cox.	H. P. Cox.	Ratio Comp. Referred to 90 Lbs.	Adiabatic Increase Ratio.	Practical Increase Ratio.	Increased Volume.	H. P. at 90 Lbs.	Eff. Cox.	Eff.
20	113	8.4	3	1.37	1.26	142	28.6	30	9
25	108	9	2.6	1.32	1.22	125	25	27	10
30	97	9.6	2.3	1.27	1.19	115	23	26	11
35	93	10.1	2.1	1.24	1.17	108	21.5	25	11.5
40	89	10.6	1.9	1.2	1.14	101	20	24	12.5
45	87	11.2	1.7	1.16	1.12	97	19.7	22	12.6
50	85	12	1.6	1.14	1.11	94	19.1	20.5	13
55	82	12.5	1.5	1.12	1.09	89	18	20	14
60	80	12.6	1.4	1.1	1.07	85	17	19.8	14.7
65	79	13	1.31	1.07	1.06	84	16.8	19.3	15
70	78	13.4	1.24	1.06	1.05	82	16.4	19	15.3
75	77	13.6	1.17	1.05	1.04	80	16	18.5	15.6
80	76	14	1.1	1.04	1.03	78	15.6	18	16
85	75	14.5	1.05	1.02	1.02	76	15.2	17.5	16.5
90	74	14.8	1	1	1	74	14.8	17	17
1	2	3	4	5	6	7	8	9	10

10,000 foot-gals. — 83,000 foot-lbs. = 2.5 H. P. theoretical.

EXPLANATION OF TABLE.

Col. 1—Gage pressures in air cyl. of pump.
Col. 2—Is the volume of free air required, calculated from Cox's computer.
Col. 3—Horse power corresponding to above volume, calculated from same computer.
Col. 4—Ratio of gage pressures in Col. 1 to 90 lbs. Standard Mining Pressure.
Col. 5—Adiabatic temperature. Ratios corresponding to pressure ratios in No. 4.
Col. 6—Are practical temperature ratios, being 70% of No. 5.
Col. 7—Is Col. 2 multiplied by Col. 6.
Col. 8—Is H. P. calculated for No. 7 by Cox's computer 76.
Col. 9—Are percentages of Col. 3.
Col. 10—Are percentages of Col. 8.

carry a low pressure. We can hardly imagine that this would be generally done and consequently we must count on the standard pressure of about 90 pounds for our economies and proportions.

After comparing the various tables of compressed air quantities for direct-acting pumps it appears that the calculations of William Cox are the most reliable, and they agree very nearly with

practical results that I have noted. He, however, like the others, considers that the pressure used by the pump is receiver pressure. The following are his principal formulæ, based on 100 feet of piston speed. Other speeds will naturally be in proportion:

$$\text{Diameter of water cylinder} = 0.54 \sqrt{\text{gallons raised.}}$$

$$(\text{Diameter of air cylinder})^2 = 0.5 \times \text{head} \times \frac{(\text{diam. of water cyl.})^2}{\text{gage pressure}}$$

$\text{Volume of free air} = 0.63 \times (\text{diam. of air cyl.})^2 \times (1 + 0.068$ gage pressure), and in general, without regard to any factors but quantity, head and pressure, we have

$$\text{Volume of free air} = \frac{0.093 \text{ foot-gallons} \times (1 + 0.068 \text{ gage pressure})}{\text{gage pressure}}$$

In using these formulæ it must always be borne in mind that the pressures given are receiver pressures; that is to say, that the compressor furnishes air to the mains at the pressures called for in the tables, and, if any higher pressures are carried in the mains, such as 90 pounds, and the air cylinder of the pump is so large that the air is wiredrawn to it, then the quantities of compressed air given should be multiplied by a constant, such as given in Column 6, Table III, when the pipes are short between the main and the pump, as occurs generally in a shaft.

The constants in Table II are simply about 70 per cent. of the ratio of the absolute temperatures due to the expansion of the air from 90 pounds to the pressures indicated in the tables, and the horse power will not be the power required to raise the pressure from atmosphere to the working pressure, but always that required to deliver it into the mains. This fact makes sorry work for efficiencies.

Inasmuch as most pumps are in the shaft near the main, a very short pipe connects them to the main, and the air is expanded through this short pipe to the pump for pressures less than that in the main. This expansion reduces the temperature of the air entering the pump to quite a marked degree, but not by the theoretical amount due to the pressure drop, for some heat from external sources is supplied, and also from the friction of wire drawing.

While I have made no experiments on this subject I have assumed that less heat would be given to this expanding air than a good water jacket would take out of the air during compression, and I have assumed the temperature to drop 70 per cent. of that due to the pressure drop. This reduces the air volume and adds to the quantity consumed by the pump, and consequently lowers its efficiency.

It would be a good practice to let this cold air gain normal temperature before reaching the pump cylinder, and this can be done by passing the water being pumped into an enlargement in the discharge pipe, within which is a coil through which the air is passed, but if no such device is used and if the air pressure in the mains is 90 pounds, we shall find that Table III expresses about the real condition of affairs for a pumping effort of 10,000 foot-gallons.

Conclusions from Table III:

First. The lower the air pressure in the main, with cylinders designed properly, the greater the efficiency, reaching as high as 30 per cent.

Second. The efficiency drops immediately if the air is expanded through the throttle into an air cylinder which requires less pressure than the main.

Third. At standard mining pressure of 90 pounds the efficiency is about 17 per cent. with properly designed cylinders, and probably drops as low as 12½ per cent. in pumps where "just one turn of the valve is open."

Fourth. Very little loss occurs in using pressures within 10 per cent. of the pressures in the main, which is ample to impart proper dynamic head to pump.

If compound compression should be used, then the efficiencies mentioned can be increased 15 per cent., and they will range then as high as 34.5 per cent. for low pressures and from 19.55 per cent. to 14.5 per cent. for standard mining pressures.

If the air is reheated, so that the pump cylinder receives it at 300° F., and if no account is made of the cost of reheating, then the efficiencies for low pressures and simple compression will be 42 per cent., for compound compression 48 per cent. and for standard mining pressures, for simple compression, 24 per cent. to 17.5 per cent. and for compound compression 27½ per cent. to 20 per cent.

According to the above table, at standard mining pressure, the efficiency, using cold air, is 17 per cent. at maximum. According to our statment, if 20 horse power produce 100 cubic feet of free air compressed to 90 pounds, 1 cubic foot will cost 6600 foot-pounds of work. Seventeen per cent. of this would be 1122 foot-pounds of useful work that the one cubic foot of free air would perform. Eleven hundred and twenty-two foot-pounds is equal to 135 foot-gallons.

I have measured the exhaust of many pumps using air at from 80 to 90 pounds, and I have found their work to be approximately 135 foot-gallons for each cubic foot of air. I have used this figure

in all my calculations for ordinary pumps, properly proportioned. Thus, to lift 200 gallons a minute 200 feet high would be 40,000 foot-gallons. This, divided by 135, would require 300 cubic feet of free air compressed to 90 pounds, which in turn requires 3 × 20 or 60 horse power to produce it. If compound compression be used, I increase the 135 foot-gallons by 15 per cent. and call it 155 foot-gallons; and, if reheating is used, in either case, I increase the 135 by the ratio of absolute temperature which I am satisfied the pump receives.

The efficiency of the direct-acting pump is shown in the diagram, Fig. 5, as follows:

With a simple compressor the M. E. P. of compression is a little more than the M. E. P. adiabatic, say 40 pounds. This cor-

FIG. 5. DIAGRAM OF ORDINARY DIRECT-ACTING PUMP.*

responds to an area on this card of M. E. P. $= \frac{\text{area} \times \text{spring}}{\text{length of card}}$; $40 = \frac{A \times 15}{7}$ or $\frac{280}{15} = 18.66$ square inches. The adiabatic volume of G, B, D, H, shrinks to A, B, C, D, before arriving at pump. The pump having a mechanical efficiency of 65 per cent., the volume I, B, E, F, is all that really does useful work. That area is 0.6 × 6 = 3.6 square inches. $\frac{3.6}{18.66} = 19$ per cent., which compares nearly with our other figures.

We found simple displacement pumps, Class I, giving 175 foot-gallons of work, and direct-acting pumps, Class II, giving

*In this and the following diagrams, atmospheric pressure = 15 pounds. Pressure scale, 1 inch = 15 pounds. Receiver pressure = 90 pounds or 7 volumes. The diagrams are here reduced to ½ size. The adiabatic area of the diagram is taken at 18.66 sq. in., or 20 H. P. per 100 cu. ft. free air compressed to 90 pounds. Compound compression area = 16 sq. in. Isothermal area = 13.44 sq. in.

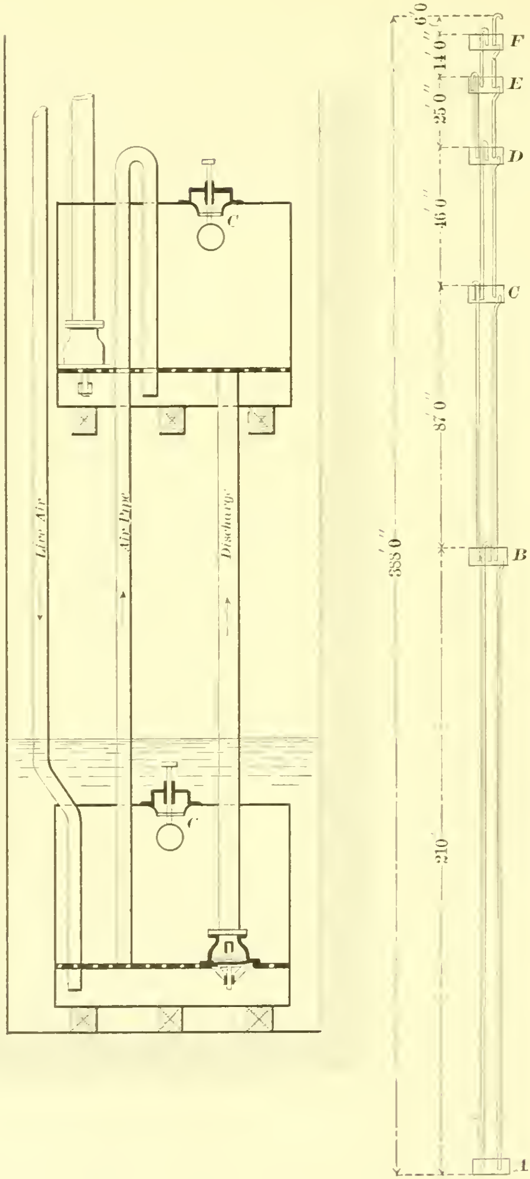

Fig. 6. Multi-Chamber Lift with Expansion.

135 foot-gallons of work. This might be anticipated, because in Class I the air is used isothermally throughout, the pressure is always exactly what is necessary, the clearance is small and there are no mechanical movements to overcome.

Referring again to the Table III, and remembering that we have assumed 90 pounds as our standard pressure in the mains, we note how serious a loss we would entertain if we used a pump having an air cylinder so large that the working pressure was 20 pounds. One not skilled might expect to get 30 per cent efficiency, but would really get about 10 per cent., or just 300 per cent. out of the way, and this justifies the remark that I have heretofore made that these catalogue tables are misleading. Except for extremely small quantities and for sinking pumps, I cannot justify the use of simple direct-acting pumps for compressed air use.

Simple displacement pumps, mentioned in Class I, can be made to use the air with at least partial expansion, and I suggest the following for your consideration and experiment. It occurred to me while searching for a cheap and economical means to do some air pumping. We will take the same problem of work at 90 pounds pressure. In order to make the problem simpler I have made it purely theoretical, and we can supply whatever efficiency coefficient we deem appropriate.

Suppose we have six equal-sized tanks, A, B, C, D, E, F, Fig. 6, arranged one above the other at distances we shall shortly determine. Suppose tank A submerged in a sump, and an air pipe conducting compressed air at 90 pounds to this tank. From each tank to the one above there is an air pipe leading from the bottom of the lower tank to the top of the upper one, as shown. From each tank to the one above there is a water discharge pipe leading from the bottom of the lower one to the bottom of the upper one, as shown, and having a check valve on its lower end to keep it full of water. From tank F the discharge is to the surface G. On each tank is a check valve C, opening the tanks to atmosphere whenever the pressure falls to atmosphere within the tanks and closing them whenever the water rises against them. Now, if tank A be full of water, and air at 90 pounds be admitted, the water will be displaced into the tank B a distance of 210 feet, just as it did with the Merrill pump, but when the water is all discharged from A, and just before the water discharge pipe is uncovered, the air pipe leading to tank B is uncovered and the air passes up into tank B, expanding against the water and pushing it up into tank C a distance equal to one-half the absolute pressure of 90 pounds. This must be so because, tanks A and B being equal, the pressure becomes 37.5 pounds in both of them when they contain air and not water, so now we have the water in C at 87 feet above B, and in a similar manner it will be pushed into D and E and F and finally out at G distances 40 feet and 25 feet, 14 feet and 8 feet

respectively, corresponding to $\frac{1}{3}$ and $\frac{1}{4}$, $\frac{1}{5}$ and $\frac{1}{6}$, the absolute pressures of 90 pounds. When D is empty the whole system is full of expanded air at 2.5 pounds, at which pressure it exhausts into the atmosphere. No mechanism is necessary except the one small valve mechanism, similar to the Merrill device, and this admits air into A at proper intervals. The rest of the tanks take care of themselves. If fine economy is not required, only the water pipe need connect the tanks, the air pipe may be eliminated and also the check valves in the water pipes, and the air will drive the water from tank to tank and finally escape. The check valves C will then drop open and air may be again admitted at A. The water pipes, being always full, do not form clearance. It matters not how much water is left in the bottom of the tanks, so long as they are all alike. That does not form clearance, and, so long as the tank is full before the valve switches, there is practically no clearance. The air, as admitted to the tanks, is made to bubble up through the water in small bubbles through a false bottom, and thus the expansion is made isothermal.

The system can be made double, or in any number of units, so that the discharge may be constant. The objection to the system for shaft work is in the space required for the tanks, which might not be objectionable in some places. For outside pumping it would be efficient and easy to install. As to economy, not much of a calculation is necessary to show that if the Merrill pump did 175 foot-gallons of work with one cubic foot of free air at 90 pounds, and lifted the water 210 feet, this system, with the same air, will do $175 \times \frac{388}{210}$ or 320 foot-gallons, because it has lifted the water $87 + 46 + 25 + 14 + 6$ feet, or 178 feet, further, or a total of 388 against 210. This makes the efficiency $22 \times \frac{388}{210}$ or 40 per cent., quite an advance over the efficiencies of direct-acting pumps.

Another peculiarity is that although 90 pounds pressure corresponds to 210 feet head, it is lifting water 388 feet, so that the cylinder ratios, as it were, are inverse.

If we now study the diagram, Fig. 7, made up from the action of this pump, and allow that the expansion is isothermal, we have A, B, D, C, as the original volume at 90 pounds in the first tank. This expands to E, F, D, I, in the second tank, and so on to atmosphere after leaving the sixth tank. It is evident that the triangular areas A, E, T, etc., six in all, are the expansion losses, but when it is considered that these expansions furnish the dynamic head that overcomes the element of time and pipe friction, we see that, even

if there is loss, it is necessary, and if the air had expanded along the isothermal line we would have been obliged to add to our initial pressure and quantity to overcome these resistances. Consequently, as a pump, it has a high efficiency, for it utilizes about all the expansion energy of the air. To calculate it from the card without planimeter, we have as follows:

The card being 7 inches long, 7 atmospheres high and 1 atmosphere to the inch, we have

M. E. P. isothermal 28.80 pounds.

We know that $\frac{\text{area of card} \times \text{spring}}{\text{length}} = \text{M. E. P.}$

Therefore, $\frac{\text{M. E. P.} \times \text{length}}{\text{spring}} = \text{area}$, or in the case $\frac{28.80 \times 7}{15} = 13.41$ square inches.

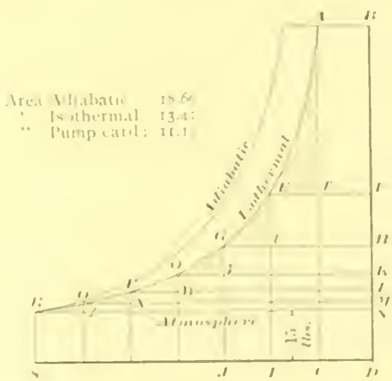

FIG. 7. DIAGRAM OF MULTIPLE DISPLACEMENT PUMP USING EXPANSION

The card being lined to square inches it is easy to add up the effective area, and we find it to be $\frac{7}{2} + \frac{7}{3} + \frac{7}{4} + \frac{7}{5} + \frac{7}{6} - 7 \times 1 = 7.05$, the latter being the area R. Q. Y., or $18.15 - 7.05 = 11.1$ net area. The curve area being 13.41, the efficiency of the pump $= \frac{11.1}{13.41}$ or 82 per cent., and, for the efficiency of the system with simple compression, we have as before, adiabatic area 18.66. The work area 11.1 divided by this, gives 59 per cent. efficiency for the system. Allowing for it the same ratio of losses, viz. 7 to 9, as we did the Merrill, we have $59 \times \frac{7}{9} = \frac{413}{9} = 45$ per cent. net, nearly the same figures we had before.

With compound compressor I should look for 50 per cent. efficiency in this system, and I hope the suggestion will prove interesting enough to encourage some one to try it.

We come now to what I deem the most interesting and useful class of compressed air pumps,—viz, the motor displacement pumps, using more or less expansion, otherwise called compound or multi-cylinder pumps.

COMPOUND OR MULTI-CYLINDER PUMPS.

Judging by results, these are very little understood, even by the people who build them, so far as their use of compressed air is concerned. The general idea has been that if the expansion of air produces such low temperatures that it frequently freezes a simple pump to a stop, it would be unwise to try further expansion in a compound pump, and consequently the compressed air users have practically avoided multi-cylinder pumps.

I hope to show that even a triple or quadruple-cylinder pump may be operated not only safely but economically, with no further addition of heat than that supplied by the water itself.

First, however, I shall speak of the phenomenon of freezing. This is a very simple matter, easily explained and easily remedied. The compressed air, being used at full pressure in the pump cylinder, is thus exhausted, and, doing its expansion work within and about the exhaust ports, reduces their temperature until ice is formed in the exhaust and finally closes the opening. I believe the action to be cumulative and on the principle used in making liquid air, for I have noticed that when once the pump cylinder becomes quite cold the choking proceeds more rapidly. The colder the air previous to exhaust, the colder will be the exhaust, which in turn makes the cylinder colder and thus the cumulative action goes on rapidly. I have heard that makers have advised short ports and conically tapered ones, with no threads, to avoid freezing. I have seen pumps with steam injected, pumps with fires under them and pumps submerged in a tank of water, all in order to avoid the freezing. Where it is not desirable to reheat pumps with steam or hot air, there are, to my mind, two simple methods of avoiding freezing; first, tap the discharge main with a quarter-inch pipe, draw down the end of this pipe until the hole is of the size of a knitting needle, introduce this small pipe well into the exhaust of the pump and let a small amount of water continually discharge therein. It will keep the temperature of the metal above freezing point and thus prevent freezing. The loss of water is very small. A pump doing 10 horse power actual work, using 250 cubic feet of free air weighing about 20 pounds, would use, I should judge, about 10 to 12 pounds of water per minute, or 1½ gallons would be ample for the work. Or, if it is not desirable to waste this water,

exhausting through a coil of thin pipe placed in a chamber, through which the suction or discharge water circulates, will furnish to the expanding air heat enough to prevent freezing.

The second method for preventing freezing would be to use compound pumps, properly arranged. This, you will note, is exactly contrary to the generally accepted practice. Inasmuch however, as a compound pump is in no wise different from two simple pumps having the same sizes of cylinder and using the same pressures, and inasmuch as the temperature drop on the initial cylinder is about one-half that of an equivalent simple pump, it is evident that it will not freeze, and, if the exhaust be carried through a copper coil over which the water being pumped flows freely, the air will become of about the same temperature as the water, and it will, thus reheated, pass to the compound cylinder at the same temperature as it entered the initial cylinder, and, passing from this cylinder, it will exhaust without freezing,and the pumping economy will be advanced 30 per cent. or more. Each cylinder would thus dispose of about half the temperature. If, however, no water heater was introduced between the cylinders, the initial cylinder would discharge the air at large temperature drop into the second cylinder. This gives a cumulative effect to the cooling at the exhaust of the second cylinder and rapid freezing up would result. This has led every one to believe compound pumps impractical for cold air, but by the introduction of the water-heated coil between the cylinders, without cost for heat units, the compound pump will not freeze and will be more economical.

It is evident that the lower the ratio of pressures the less the ratio of temperatures and consequently the less liability to freezing.

To return now to the compound, direct acting pump.

Compound pumps of the better class can be given a mechanical efficiency of 70 per cent., which covers losses in the air and water cylinders and the friction in the pipes, with an allowance for dynamic head. Their economy depends upon the character and amount of the reheating applied to the air.

There are four general classes:

1. Reheating with the water pumped.
2. Extraneous heating before the initial cylinder.
3. Extraneous heating before the compound cylinder.
4. Extraneous heating before both cylinders.

In the first class for mine pumping the temperature of the water may be generally assumed to be 60°, and the heater is a shell filled with copper tubes and preferably made a part of the suction pipes, the water flowing around the tubes through which the air is

exhausted from the first cylinder to the second. A steam heater, of the Wainwright type, gives the idea, and about one square foot should be allowed to every five cubic feet of free air. As stated before, its action is to restore to normal temperature the compressed air exhausted from the initial cylinder, thus delivering it to the second cylinder at the same temperature as to the first, just reversing the action of the inter-cooler during compression, and, inasmuch as the cylinders use the air at practically full pressure, the expansion takes place in the reheater. The diagram, Fig. 8, shows what takes place as far as economy is concerned. B, C, D, E, is taken at 70 per cent. of the volume furnished to the pump to cover the mechanical efficiency. This expands 2.65 times (when the initial pressure is 90 pounds) in the reheater and F, E, H, G, is the volume given the second cylinder. The areas $= 0.7 \times (7 - 2.65)$

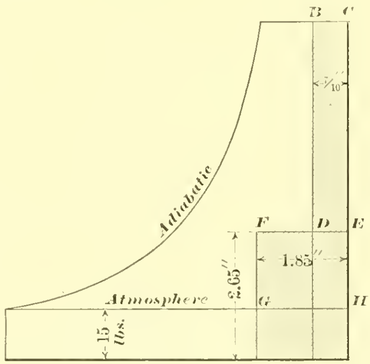

Fig. 8. Diagram of Compound Pump. Water Reheated.

$= 0.7 \times 4.35 = 3.045 + (1.855 \times 1.65) = 3.06 = 6.1$ square inches. It will be noted that the work in both cylinders is alike—$\frac{6.1}{18.66} = 32.7$ per cent. against 19 per cent. that we figured by the same method for the simple pump. This is a very large gain and it costs nothing to maintain it, the first cost of the heater being small. I cannot conceive of a more forcible argument in favor of compound pumps.

For compound compression this efficiency will be increased to 37.5 per cent. If our simple pump did 135 foot-gallons of work then this style of compound will give $135 \times \frac{32.7}{19} = 232$ foot-gallons for a cubic foot of free air compressed to 90 pounds gage.

In compound pumps, where we have extraneous heating previous to the admission of the air into the initial cylinder, let us suppose the heating to be 283° F. This will be sufficient to increase the volume from $\frac{7}{10}$ in our former example to 1, in other words, to off-

set all the mechanical losses in the pump, and the initial cylinder will be full of air at 90 pounds and 743° absolute or 283° F. When the air is exhausted from this cylinder into the low-pressure cylinder there is an expansion ratio of 2.65 between the cylinders, provided there is a small receiver between the two cylinders; the temperature will drop a ratio of 1.32, or, considering the losses of radiation, will reach 60° again and will enter the low-pressure cylinder in precisely the same condition as in the former case, and with the same volume. Consequently we have no gain in this way of reheating, except for the initial cylinder, unless the heating be carried so that the cylinder will receive it at more than 283°, which might not be practical. Referring to our last diagram, Fig. 8, we note that we have added the area I, B, D, J, to our economy diagram, and the diagram, Fig. 9, is the result. The area of useful

FIG. 9. COMPOUND DIRECT-ACTING PUMP. REHEATED TO 300° BEFORE THE INITIAL CYLINDER.

work will be $1 \times 4.35 + 3.06 = 7.41$, and, the compression area being 18.66, the efficiency is $\frac{7.41}{18.66} = 40$ per cent., against 32.7 per cent. in the former case, and for compound compression this will be 46 per cent., and the foot-gallons of work will be 280 for each cubic foot of free air compressed to 90 pounds gage.

If, however, there be a reheating between the two cylinders to 283° F., then the volume entering the low-pressure cylinder will be increased about 1.43 per cent., and, instead of 1.85 per cent., as on the former diagram, it will become 2.65 per cent. and will occupy the area shown as K, E, H, L in diagram, Fig. 10.

The useful area in this card will be $4.35 + 4.35 = 8.7$. It will be noted that the work is the same in both cylinders and the final efficiency will be $\frac{8.7}{18.66} = 46$ per cent. If compound compres-

sion is used it will become 53 per cent., and the foot-gallons of work it will perform will be 326.

It will be noted that the points K and L are on the isothermal curve, which means that we have utilized completely the full pressure work within the isothermal curve, using two expansions, and if three cylinders be used and proportioned by the same rule, we make a still further gain, as per diagram, Fig. 11, giving 54 per cent. for simple compression and 62 per cent. for compound compression. The foot-gallons of work it will perform will be 383. These figures are perfectly practical and rather under the mark.

It is easy to see that more cylinders would add to the economy, but, inasmuch as three are practical and four are too many, we may as well stop here. For higher economy on this system the reheating must be carried higher, inasmuch as 400° is perfectly

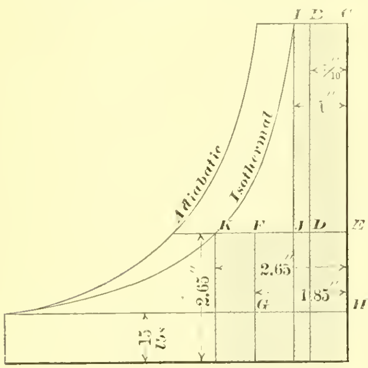

Fig. 10. Compound Direct-Acting Pump. Reheated to 300° before Initial and Low-Pressure Cylinder Using Fuel Pressure Only.

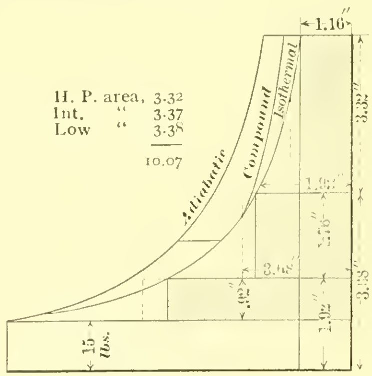

Fig. 11. Three-Cylinder Reheated Compound Pump. Using Full Pressure Only.

practicable and as easy to obtain as 300°. This would add 16 per cent. to our area and give 63 per cent. and 72 per cent., respectively; our foot-gallons of work would be 444 foot-gallons, and the dotted lines on the diagram will represent the shape of the card and show how it may extend over the isothermal curve. This I call the practical limit.

We have seen that a cubic foot of free air at 90 pounds pressure will perform, under proper conditions, 444 foot-gallons of work. This is 3685 foot-pounds, which may be decreased 5 per cent. on account of the cost of reheating, making net 3500 foot-pounds of work. On account of the 70 per cent. efficiency of the compound pump, we gave it one cubic foot of free air in our calculation and called it $\frac{7}{10}$. The air itself must be given credit for

thus, and if, in the 70 per cent. efficiency pump, it did 3500 foot pounds of work, it really was yielding up $\frac{3500}{.70}$ or 5000 foot pounds.

It takes 5000 foot pounds of work to compress this air in a compound compressor. The air has therefore shown, in its work, an efficiency of 60 per cent. as a motive power, at 90 pounds pressure in triple, compound, direct acting pump cylinders, triple reheated to 300°, a result entirely different from what we are in general almost forced to believe.

Figs. 12 and 13 show two actual cards illustrating the principle of full pressure working. It will be noted that the expansion shown is small, and, if the reheater had a little larger capacity, the diagram would be rectangular.

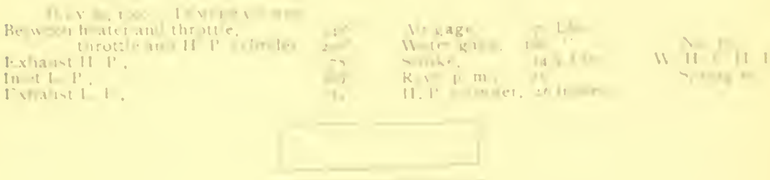

FIG. 12

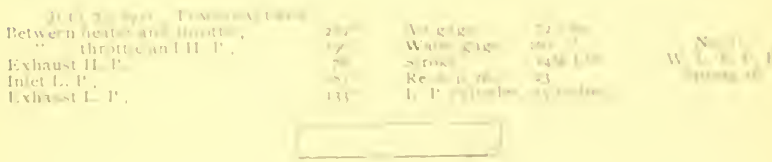

FIG. 13

Unfortunately, at the time these cards were taken, the pump was throttled, and the air was drawing from 70 pounds to 50 pounds, so that its efficiency is diminished. The pump, however, was delivering 300 gallons per minute 300 feet high, consuming 600 cubic feet of free cold air at 50 pounds pressure, and giving 250 foot-gallons per cubic foot of free air, at 50 pounds pressure, with an efficiency, referred to 50 pounds, of 65 per cent.; referred to 70 pounds, of 52 per cent.; the total energy, from 70 pounds to 50 pounds, being lost in the throttling of the pump. It illustrates, however, our proposition and confirms our figures.

It seems to be generally believed that the best result, in compound pumps using compressed air, is obtained when we get as much expansion within the cylinders as is possible, and the highest efficiency which could be obtained in this manner would be when there is no drop whatever between the high and low-pressure cylin-

der, and the air is expanded to atmosphere in the low-pressure cylinder as shown by the ideal card, Fig. 14. This would require heating to 454° F., the temperature of adiabatic compression.

The practical action of a once reheated compound pump is as follows: The air enters the high-pressure cylinder, we will say, at a temperature of 200°, and at 100 pounds pressure. This air operates at full pressure throughout the whole stroke, and there is no drop whatever in its temperature; the exhaust valve opens, there being a considerable space between the high and the low-pressure cylinder (in the shape of pipes and clearances, and, if there be an intermediate reheating, in the additional space for the reheater); the pressure immediately drops, we will say, to 50 pounds, and the temperatures suffer in adiabatic proportion to the absolute pressures.

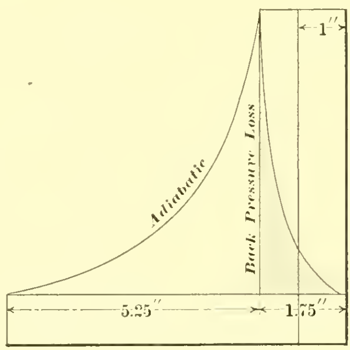

Fig. 14. Ideal Compound Card. Air Heated to 454° F.

This expansion from 100 pounds to 50 pounds does no work whatever and is entirely lost. The volume of air shrinks in proportion to the absolute temperature, and then passes into the low-pressure cylinder and immediately commences to expand therein as the piston commences to move. Here will be a case of adiabatic expansion, for the temperature in the cylinder must drop as the pressures drop, and the expansion takes place adiabatically to the end of the stroke, where, with a terminal pressure, we will say, of 10 pounds, it drops out into the atmosphere at a temperature probably a few degrees below that of the atmosphere.

The M. E. P. of the expansion from 50 pounds down to say 10 pounds is not a very large proportion of the total possible expansion work of the air from 100 pounds down to 10 pounds, and this is still further reduced by the fact that, while we have the expansive work in the low-pressure cylinder, we have also a variable

back pressure on the high-pressure cylinder, which means an unequal load on the piston and a consequent variable speed.

An attempt has been made to realize the work of expansion between the two cylinders; but, owing to the natural mechanical construction of the pump, it is impossible to realize but a small part of it, and I believe the correct method of operating these pumps is to do all the expanding between the cylinders, restore the volume by reheating and use only full pressure in the cylinders. We thus avoid any temperature drops in the cylinders and we have a constant pressure therein, and a consequent constant speed and constant back pressure.

In a compound pump the proportion of the low-pressure cylinder to the high will be larger than what is in use at present, for the low-pressure cylinder will be operated at its terminal pressure throughout the stroke. In other words, the card will be rectangular.

We believe that, instead of using two cylinders, with a greater ratio of area, it would be better to use three cylinders and so to proportion the area between them as to have the terminal pressure desired. In this way the drop between the cylinders will be small, and the opportunity to take advantage of double heating considerable. The ideal situation, theoretically speaking, would be where a large number of cylinders are in operation, one after the other, with only a sufficient drop between them to give them the necessary dynamic head. The combined card would then represent a series of steps considerably overlapping any possible card that could be made by an adiabatic expansion.

If it were possible ordinarily to expand without drop from the initial pressure, there would be no criticism of ordinary methods; but, inasmuch as a drop must be made, the question naturally arises, Is it not better to make the complete drop and take advantage of the situation when the drop occurs, an advantage which is neglected when a combination is made of half drop and half expansion? The Comstock offers every possible opportunity for this kind of a proposition. The temperature of the water is 120°, and the pump, the water, the intercoolers, the air and everything will always be at that temperature, except if the air expands in any one of the cylinders. It is well known that air is such a poor conductor of heat that no matter if the cylinder walls be hot it will drop its temperature in expanding. In other words, the expansion in the cylinders would be adiabatic; whereas, if a complete drop is made and the temperature restored between the cylinders, and if then it is used in the cylinders at full pressure throughout the

stroke, it will approach nearer an isothermal expansion for the air than any other kind of a practical method with direct-acting pumps.

The economical expansion of air must ever be the exact reverse of the economical compression of air, and the ideal air compressor would be one of many stages with a small rise in pressure between each two stages, just sufficient to keep the air moving, and an intercooler to take out this small increment of heat between every two stages, making a practically rectangular card between each two. The natural reverse of this, for the economical expansion of air, would be a multitude of cylinders, with sufficient drop between each two to maintain a circulation of the air, and a reheater between each two cylinders, making a practically rectangular card for expansion in each cylinder.

As illustrating the principle which I advocate, attention is called to Fig. 15, showing two diagrams from a compound pump, reheated before the initial cylinder to 165° F. This pump is doing fair work, raising 450 gallons per minute 424 feet high. It receives air at 63 pounds gage and 165° F., takes air at practically full

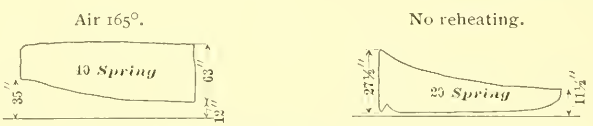

FIG. 15. CARDS FROM COMPOUND PUMP 14″ + 24″. CYLINDER HEATED TO 165° BEFORE INITIAL CYLINDER.

stroke, exhausts into the pipe connecting the two cylinders, drops to 35 pounds gage and gradually expands as back pressure against the high-pressure piston, until 12 pounds is reached. The low-pressure piston receives the pressure at 27½ pounds and the air is expanded to 11.5 pounds. It then exhausts, against 2 pounds back pressure, into the atmosphere.

Assuming the volume of the high-pressure cylinder to be one cubic foot and having no clearance, etc., inasmuch as we are about to make a comparative statement, we find that the work on the high-pressure piston is 6797 foot-pounds and on the low-pressure piston 1581 foot-pounds, a total of 8378.5 foot-pounds.

Let us consider another method. If we use the pressure at 63 pounds on the same high-pressure piston and let the exhaust make a complete drop to 11.5 pounds, the work on the high-pressure piston will be 7416 foot-pounds, and if we reheat in the receiver to 165° and construct the low-pressure cylinder of such a size that after receiving the air at 11½ pounds it will exhaust at 2

pounds, thus preserving the relation of the previous problem, the cylinder ratio will be 3.06 and the work on the low-pressure cylinder becomes 4186 foot-pounds, making a total of 11,602 foot-pounds, or a gain of 40 per cent. again.

Suppose we make it a triple-cylinder pump, make each cylinder do the same work, reheat to 165° before each one and use the same 2 pounds back pressure, then the initial cylinder will take the pressure at 63 pounds and do 4550.4 foot-pounds, the intermediate will take the pressure at 31 pounds and do 4450.4 foot-pounds of work, and the low-pressure cylinder will take the pressure at 12.4 and do 4550.4 pounds and will exhaust at 2 pounds back pressure, making a total of 13,651 foot-pounds, or a gain of 64 per cent.

The pump is now doing about 220 foot-gallons of work. If we add 64 per cent. to this we will have 360 foot-gallons. We claimed 383 in our former diagrams, for higher reheating, which checks results quite nicely.

The cylinder ratio in the foregoing will be, for equal work in the cylinders, the cube root of ratio between initial and absolute pressures, 1.7, making the pressure 63, 31 and 12.4, respectively. The atmospheric pressure was 13.5 pounds.

Your attention is particularly called to the difference between steam and air practice, for here is a triple expansion, so called, operating with 63 pounds initial pressure properly. The number of cylinders that could be properly used will have to be determined by practice, the limit being when their mechanical deficiency offsets their economy.

There are many places where it would be inadvisable to use fire or steam for reheating, on account of heat or annoyance or expense, and it is in such situations that what I term a water reheater will supply enough heat units to render the pumping economical. A general illustration of this is given in Fig. 16, which shows how the suction water may, in passing around corrugated copper tubes, render valuable service in heating the air.

In actual practice the difference in the revolutions of the compressor, to do the same work, speaks immediately for the economy of the apparatus. In pumping muddy water through the reheater the deposit of mud on the tubes could be readily noticed by the increased air consumption. It is very evident that the more air cylinders on a pump the less drop in pressure will be made from one cylinder to another, and consequently less dropping of temperature. It is for this reason that, in a multi-cylinder pump, water at ordinary temperatures, acting through a number of cylinders, will yield up as many and perhaps more heat units for useful work

than a high temperature reheating before the first cylinder. It gives more time for convection, and with air, which is a poor conductor, time is required.

Referring to our last example, using three cylinders, it is evident that if the water was at 60° F. and if the air was delivered to each cylinder at 60° F., the only difference in results would be the increased volume due to the higher temperatures. This we counted as $\frac{1}{5}$. Deducting, therefore, 20 per cent. from 13,651 foot-pounds, we have 10,921 foot-pounds, which would be accomplished

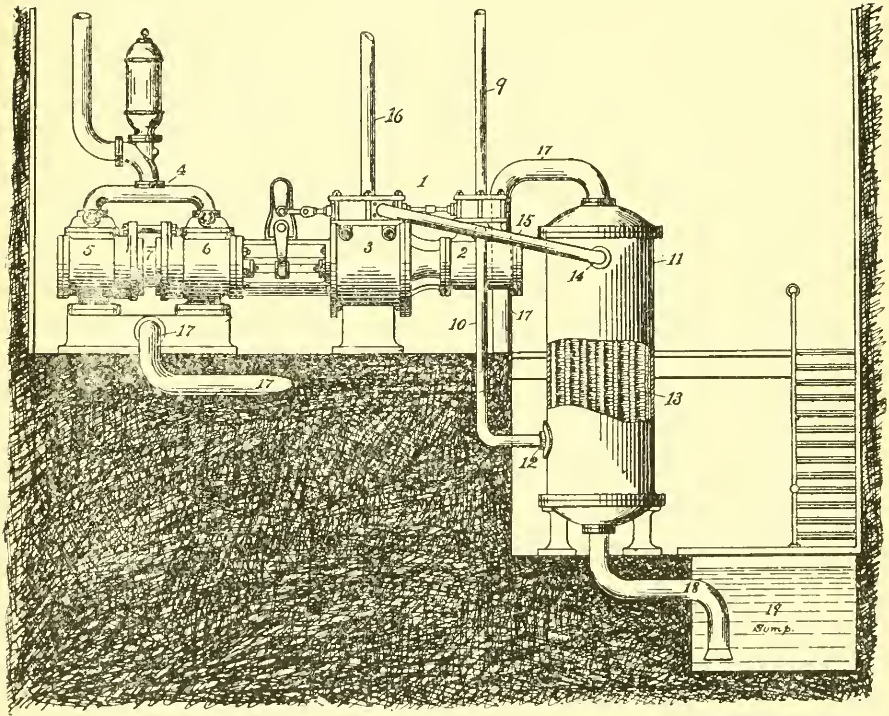

Fig. 16. Rix Compressed Air Heater, Using Water Being Pumped.

on the water-heating plan, which is more than was accomplished by heating the initial cylinder of a compound pump to 165°. Please note that this heating costs nothing and that the extra cost of the pump should not be considered. If, by water reheating, a triple cylinder pump will do 300 foot-gallons per minute, the cost for pumping water would be one-half what it would in an ordinary direct-acting pump, which power saving would of itself soon pay the cost difference.

COMBINATION OF DISPLACEMENT AND AIR-LIFT.

It seems proper, under the head of air-lift pump, to speak of the Wheeler pneumatic pump, which is a combination of displacement and air-lift, and can be used in places where there is no proper submersion for the air-lift. In fact, the system might be

FIG. 17. A IS DISPLACEMENT CHAMBER RAISING WATER TO C WHEN AIR FROM PIPES AT B COMPLETES THE LIFT

called an air-lift system with artificial submersion, shown generally in Fig. 17.

The pump has two displacement chambers and an automatic valve attached, as in the Merrill pump, and the displacement action takes place similarly, one chamber filling while the other empties.

The exhaust being into the atmosphere, the expansive work of the air is lost. The Merrill pump discharges from the chambers directly to the final point of delivery, while the Wheeler pump keeps the discharge pipe filled with water at a certain height, and an air jet at its lower extremity air lifts this water to the final delivery. H. C. Behr, Esq., tested this pump during last year, and his conclusions in his report are as follows: That the efficiency of the machine as tested is such as to compare not unfavorably with the ordinary steam or air-driven direct-acting pumps of moderate size as underground in mines; that the operating expense could generally be expected considerably lower than for such pumps, on account of slight cost for repairs and replacement of worn parts; that it should require less skill and experience to operate and maintain this pump than a direct-acting pump. The efficiencies found might be somewhat increased in cases where a very efficient compressing plant is available. The efficiency will not compare favorably with high-class, air-driven compound pumps reheated. The objection to the pump is that it is not capable of raising the water by suction and is thus incapable of charging itself. It must be submerged, or the supply must be higher than the water chambers.

This method of pumping permits the displacement to take place with low pressures and thus adds to the efficiency.

Table IV accompanies Mr. Behr's report.

Test No. 21 shows the highest efficiency,—viz. 33 per cent. The air pressure was 33.75 pounds, work done 4 horse power, water lifted 1271 pounds, quantity of air 7.78 pounds per minute. Comparing this with the results obtained in the discussion of air-lift and simple displacement pumps, we have: Air pressure, 33.75 pounds; 10 per cent. for dynamic head, equals 30 pounds for active pressure. The equivalent head is 70 feet, consequently the water will stand 70 feet in the discharge pipe and the air-lift will be 35 feet, giving a submersion of 2 to 1, and air-lift pressure of 33.75 pounds.

Referring to the tables of air-lift experiments, we find that 2 cubic feet of air to 1 of water will do the work. Practically 20 cubic feet were lifted, making 40 cubic feet of air required at 33.75 pounds pressure, or 4.8 horse power. The displacement of 20 cubic feet of water at 30 pounds required 22 cubic feet of air at 33.75 pounds pressure. Allowing 10 per cent. clearance, which was 72 cubic feet of free air, this, at 12 horse power per 100, equals 8.64 horse power. $8.64 + 4.8 = 13.44$ horse power, almost identical with results shown in the table.

There can be no question that the economy of this system

could be greatly enhanced by using the expansive force of the air that is lost in exhausting from the displacement chambers, and one of the easiest means of doing this is on the principle which I suggested for the multi-stage displacement pump, as illustrated in Fig. 6.

TABLE IV.

RESULTS OF TEST OF WHITTIER PNEUMATIC PUMP.

By H. C. Behr

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Test Number.	Average Air Pressure above Atmosphere.	Weight of Air Used Lbs. per Minute.	Weight of Water Pumped Lbs. per Minute.	Number of Pump Strokes Approximate per Minute.	Water H. P. Work Realized or Water Lifted to Height of 105 Feet.	Efficiency Based on Comparison of Work Returned with Least Work Theoretically Needed for Compression.	Efficiency of Compression in Ordinary Practice.	Total Efficiency Product of Columns VII and VIII Multiplied by .85 for Efficiency of Compressing Mechanism	Operating H. P. Work Spent, Indicated Work of Steam or Power Required at Motor Shaft
	Lbs. per Sq. In.	Lbs.	Lbs.	Per Minute	H. P.	Per Cent	Per Cent.	Per Cent.	H. P.
5	41	12.27	1,971	18	6.271	42.48	69.4	25.02	25.06
14	39	12.05	1,948	18.5	6.198	41.75	70.6	25.[illegible]5	24.74
13	39	9.137	1,481	15.5	4.712	44	70.6	26.4	17.84
2	34.5	13.106	1,888	17	6.007	41.01	73.3	26.08	23.03
12	34.5	9.079	1,423	15	4.528	45.52	73.3	28.36	15.06
21	33.75	7.78	1,271	12.75	4.033	48.00	73.8	30.17	13.36
15	33.5	11.02	1,716	16.25	5.46	46.04	73.9	2[illegible].9	18.20
1	33	13.687	1,935	18	6.158	42.08	74.2	26.53	23.21
6	30.375	5.77	785	8.2	2.407	42.8	75.8	27.4	9.11
3	29.5	13.00	1,668		5.309	40.56	76.3	26.3	20.18
22	29.25	9.81	1,426	14.5	4.[illegible]86	44.86	76.5	29.24	15
20	29.125	7.65	1,102	11	3.506	46.12	76.7	2[illegible].9	11.72
4	27.25	13.8	1,633	15.5	5.196	39.33	78	26.07	10.93
17	24.125	10.08	1,160	13.[illegible]	3.69	39.84	79.5	29.9	13.71
9	24.125	5.34	730	7.75	2.323	50.15	79.5	33.9	6.85
10	23.75	10.12	1,133	11	3.605	40.43	79.8	27.4	13.15
18	19.625	7.39	608	6	1.935	33.54	82.2	23.4	8.22
11	19.5	9.397	834	8.25	2.654	36.35	82.3	25.4	10.[illegible]5
19	19.375	7.6	626	8.5	1.992	33.89	82.4	23.7	8.4
7	19	9.78	856	7.8	2.724	39.35	82.6	25.5	10.63
8	14.5	7.14	350	4	1.114	24.14	85	17.44	6.5

Column pipe, 4 inches diameter.
Lift, 105 feet.

NOTE.—Test No. [illegible] was thrown out [illegible]

CUMMINGS OR TWO-PIPE SYSTEM.

This is a simple system, compressing the air to a high pressure, say 200 pounds per square inch, and exhausting it back from the motor at 100 pounds per square inch, the idea being that full pressure motions are more economical the nearer we approach high pressures. For instance, from 0 to 100 pounds we observe quite

an extended compression curve, while from 800 to 900 pounds there would practically be no curve, but simply full pressure work, the part one wishes to utilize in direct-acting pumps.

In card No. 1, Fig. 18, the compression area is A, B, C, F, only, the area A, F, C, H, being always back pressure. The area of the compression is therefore 8 square inches, the work done is calculated at 70 per cent. as with the other examples, and this area will be $3.04 + \frac{3.04}{8'} = 38$ per cent., and if reheating be used to 300° and the exhaust be cooled off before returning to compressor, the efficiency will be 50 per cent., almost double the efficiency of the ordinary direct-acting air pump. If now we look at diagram No. 2, where we compress from 90 to 180 and exhaust at 90, we have an efficiency of 50 per cent. cold, which, by reheating to 300°, would be increased by $\frac{7}{5}$ or to 70 per cent.

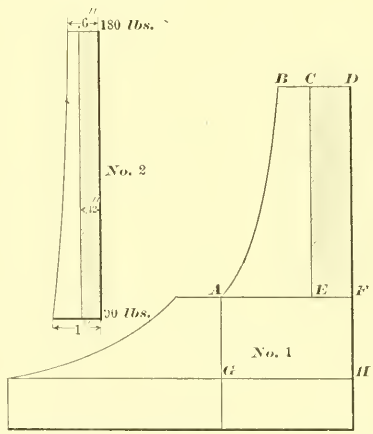

Fig. 18. Diagram Illustrating the Cummings' System.

These percentages are probably marred by frictions and leakages which I have no means of ascertaining, but I should judge that these could be kept within 10 or 15 per cent., making the simple pump show an efficiency of probably from 50 to 60 per cent. with compound compression.

These pumps can also be compounded with considerable gain, but such treatment would easily form the subject for another paper. I cannot understand why this system has not been pushed for compressed air station pumping. I believe it will be very satisfactory and economical, and some day will be extensively used. It has one advantage over the Harris system, inasmuch as the back pressure is constant, and ordinary pumps may be operated with it. The

principal objection is the high pressure and consequent leakage, and the double set of pipes and joints. This system should be regarded with high favor.

AIR-LIFT PUMPING.

While the air-lift system of pumping has recently been brought to the attention of the public, it is not a new thing, there being records of its use more than 100 years ago.

The honor of putting the air-lift system in practical shape is due to Dr. Julius Pohle, who came to San Francisco from Arizona, where he had been experimenting with several plants, one with a lift of 300 feet. Dr. Pohle established himself at the office of Rix & Firth, who interested themselves to the extent of expending considerable money in experiments to determine the efficiency of the system. A 10-inch well was sunk 60 feet deep on a piece of property belonging to the Mechanics' Institute, San Francisco. The bottom was cemented, a gallows frame 75 feet high was erected over it, and a tank and weir constructed over the well to measure the water flow. Air and discharge pipes were arranged, so that many different ratios of lift and submersion could be tried. The compressor had a compound air cylinder, actuated by a Corliss engine of 50 horse power.

The well-known civil engineer, Mr. B. M. Randall, conducted the experiments, and they were made on August 27, 1899. The results showed efficiencies as high as 52 per cent.

The records of this test are given in Table V. They are of interest as forming the first record of results in the history of air-lift pumping.

The method of operation of the air-lift is too well known to require description here.

Messrs. Brown and Behr tested the experimental plant referred to, and, in a paper read before this Society in 1890, stated that the greatest efficiencies were obtained when the submersion of the pipe was twice the lift, and with this submersion an efficiency of 50 per cent. was obtained.

Quite extensive experiments have been made in Germany to determine the efficiency of the air-lift, and their results fall somewhat short of the percentages obtained in this country. The efficiency was the ratio of work in discharged water to the indicated compressor work and ranges from 45 to 30 per cent., with smooth pipes,—a lift of 50 feet, and a submersion of from 4 to 3, to 3 to 2.

The amount of water discharged increases with the quantity as well as with the pressure of the air, but the efficiency falls away

TABLE V.—Experiments with Pohle Air-Lift, 1889.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.
Number of Tests.	Number of Compressor Strokes per Minute.	Pressure per Sq. In. in Receiver.	Weir Head. Inches.	Length of Water Pipe below Surface of Water. Ft.	Length of Water Pipe below Surface of Water. Ft.	Temperature in Receiver. Fah.	Temperature of Air in Room. Fah.	Temperature of Water at Weir. Fah.	Quantity of Water Pumped per Second. Cu. Ft.	Weight of Water Pumped per Second. Lbs.	Quantity of Water Pumped in 24 Hours. Gallons.	Work per Second of Pumping the Water. Foot-Lbs.	Air at 75° Fah. Compressed per Second. Cu. Ft.	Work of Compressing Air per Second. Foot-Lbs.	Resistance in Water Pipe. Foot-Lbs.	Resistance of 3 Bends in Air Pipe. Foot-Lbs.	Resistance of 3 Bends in Air Pipe. Foot-Lbs.	Resistance of ⅝" Nozzle in Air Pipe Foot-Lbs.	Resistance of Circular Bend in Water Pipe. Foot-Lbs.	Resistance due Velocity of Discharge. Foot-Lbs.	Sums of Work of Pumping and Resistances as Determined. Foot-Lbs.	Efficiency of Pump. Per Cent.
1	59	31.15	4.1	75.55	55.78	77°	72.6°	68°	0.0799	11.25	116.576	850	1.086	2,616	832	652	80	88	8	63	2,583	33
2	45	27.86	3.8	75.55	55.78	78°	70.7°	68°	0.1488	9.3	96.4	703	.878	1,864	481	325	39	38	5	37	1,628	38
3	30	25.64	3	75.55	55.78	79°	74°	68°	0.0824	5.15	53.495	389	.552	1,180	159	155	19	14	1	13	1,050	33
4	59	30.69	5.2	35.53	55.5	74°	72°	71.6°	0.3259	20.37	281.578	724	1.076	2,569	1,050	458	80	88	15	58	2,473	28
5	46	26.4	5.1	35.53	55.5	78°	71.6°	68°	0.3105	19.41	201.204	690	.846	1,842	570	400	48	48	10	68	1,834	37
6	30	24.78	4.6	35.53	55.5	78°	73.2°	68°	0.2398	14.99	155.39	533	.552	1,155	325	155	19	14	4	33	1,083	46
7	22	24.16	4.25	35.53	55.5	78°	72.5°	68°	0.1968	12.3	99.662	437	.405	834	160	97	11	11	2	18	736	52.4
8	60	24.1	3.85	54.7	36.33	78°	73°	70°	0.1538	9.61	60.329	526	1.104	2,269	631	580	89	86	9	12	1,933	23
9	35	17.58	3.15	54.7	36.33	78°	73°	70°	0.0931	5.82	37.325	318	.644	1,072	118	190	29	28	2	14	699	30
10	22	16.17	2.6	54.45	36.58	74°	74°	69°	0.0576	3.6	62.726	196	.405	636	36	77	11	11	5	4	340	31
11	60	20.58	3.2	63.16	27.87	80°	77°	69°	0.0968	6.05	21.902	382	1.104	2,046	137	281	89	86	2	44	1,021	19
12	60	18.75	2.1	70.66	20.37	76°	72°	69°	0.0338	2.11	42.962	149	1.104	1,851	401	514	89	86	6	15	1,260	8
13	38	15.29	2.75	63.16	27.87	80°	74.5°	70°	0.0663	3.96	11.988	250	.669	1,051	106	194	35	34	2	12	633	24
14	19	12.28	1.65	63.16	27.67	79°	75°	71°	0.0185	1.16	72.965	70	.35	450	8	54	8	8	0	1	147	16
15	34	12.35	3.4	31.5	20	79°	71.5°	69°	0.1126	7.04	147.696	222	.616	795	80	137	28	28	2	15	508	28
16	60	20.46	4.5	25.25	26.25	69°	66°	67°	0.227	14.19	131.285	358	1.104	2,039	618	495	89	86	15	115	1,775	18
17	41	15.8	4.3	25.25	26.25	70°	66°	67°	0.2026	12.66	98.247	320	.754	1,175	280	230	41	39	7	52	969	27
18	22	12.52	3.74	25.25	26.25	70°	66.5°	67°	0.1439	8.99	93.286	226	.405	528	66	65	11	11	1	12	392	43
19	60	22.13	5	20.25	31.25	72°	67.5°	69°	0.2954	18.46	147.296	374	1.104	2,147	832	537	89	86	20	152	2,090	17
20	27	15.22	4.5	20.25	31.25	72°	68°	69°	0.227	14.19	139.061	287	.497	748	167	110	18	17	4	32	635	37
21	22	14.52	4.4	20.25	31.25	72°	67°	69°	0.2146	13.42	232.826	272	.405	589	118	71	11	11	3	22	507	46
22	60	23.12	5.4	15.25	36.25	74°	67°	68.5°	0.3593	22.45	211.183	312	1.104	2,209	926	582	89	86	25	141	2,091	16
23	30	17.46	5.2	15.25	36.25	73°	69°	69°	0.3259	20.37	164 01	311	.552	911	352	111	19	14	10	66	883	34
24	19	16.2	4.72	15.25	36.25	73°	69°	69°	0.2531	15 82	44.906	241	.35	550	133	59	8	8	3	25	477	44
25	60	17.05	2.8	36	15.5	74°	69.5°	69.5°	0.0693	4.33	27.475	156	1.104	1,800	182	398	89	86	5	34	950	9
26	34	10.17	2.3	36	15.5	74°	70°	70°	0.0424	2.65	6.026	93	.616	880	37	123	28	26	1	7	315	11
27	18	7.46	1.25	36	15.5	73°	70°	70°	0.0093	0.58	9.461	21	.331	288	2	36	7	7	0	14	73	7
28	60	15.87	1.5	41	10.5	76°	72°	70°	0.0146	0.92	116.575	38	1.104	1,712	38	360	89	86	1	7	619	2
30	60	31.66	4.1	75.78	55	82°	70°	10.8°	0.1799	11.24	109.577	852	1.104	2,685	836	674	89	86	9	65	2,611	32
31	60	31.66	2.9	75.78	55	84°	71°	110°	0.1691	10.57	44.054	801	1.104	2,685	792	674	89	86	9	70	2,521	30
32	28	25.28	4.1	75.78	55	84°	71°	114°	0.0757	4.73	49.554	359	.515	1,091	92	161	19	18	1	7	719	33
33	60	31.66	4.1	75.8	55	81°	70°	116°	0.1799	11.24	116.575	852	1.104	2,685	836	674	89	86	9	65	2,611	32
34	60	31.28	4.1	75.8	55	80°	70°	82°	0.1796	11.24	116.575	851	1.104	2,666	836	674	89	86	9	65	2,610	32

very rapidly when the output is forced. A submersion of 50 feet and a height of discharge of 25 feet, with increasing quantities of air, gave quantities of water from 4 to 15 cubic feet per minute. The quantity of air varied from 76 to 105 cubic feet per minute, and the ratio of free air to the water lifted varied from 1.96 to 7.6, the efficiency being in a like proportion.

In another set of experiments, with lifts from 43 to 230 feet, submersion from 92 to 400 feet, from 2.9 to 5 cubic feet of air was required per cubic foot of water pumped, and the pressures were from 30 to 160 pounds.

The quantity that can be handled is practically unlimited.

It is safe to calculate on velocities in the pipe from 4 to 8 feet per second, and it will take from 2 to 3 cubic feet of atmospheric air per cubic foot of water pumped for heights from 15 to 50 feet, and from 50 to 100 feet I should figure on from 3 to 4 cubic feet of air per cubic foot of water.

I believe that for very low heads the air consumption may be still further decreased, and that 1.5 cubic feet of air will lift a cubic foot of water 20 feet high.

Engineering News, Vol. XXVII, page 140, gives some interesting data on air-lift pumping at Rockford, Ill.

The pumping was done from four wells, 84 feet, 84 feet, 82.5 feet and 59 feet from surface to water while being pumped and 7½ additional into a tank with an air pressure of 76 pounds per square inch.

The wells were close together. A 2½-inch pipe led from the reservoir to each well and a 1½-inch pipe was continued in the well casing with 225 feet submersion.

The discharge was 2,000,000 gallons per 24 hours. From the steam indicator diagrams it appears that 124 horse power was used. The average yield was 1401 gallons per minute, and the net work done was 24 horse power on an efficiency of 20 per cent.

A 14 x 22 duplex compressor made 96 revolutions to do the work. This would give about 600 cubic feet of free air. About 200 cubic feet of water were pumped, or 3 cubic feet to 1, a result which represents the average. The efficiency is low because the compressor took too much power. In a compound compressor 600 cubic feet of air should be compressed to 76 pounds for an expenditure of not more than 100 horse power. This would make the efficiency about 25 per cent.

The air pressure was excessive, and this was due no doubt to the small well casing, because with proper well pipes 50 pounds air pressure would have been ample.

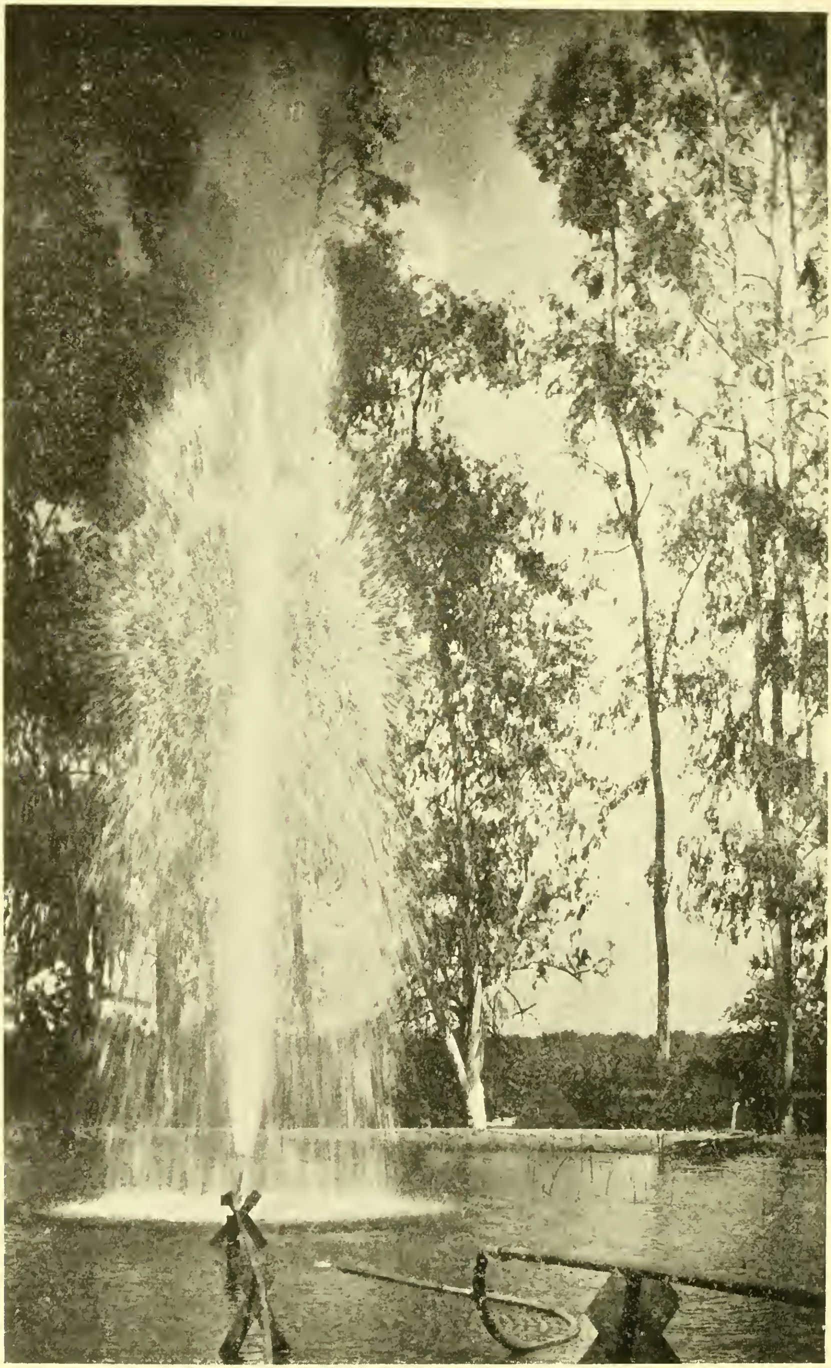

Fig. 19.

I have not yet succeeded in making any general rules for sizes and capacities for air-lift pumping. There is generally a surprise waiting for us, no matter what we do. There should be some particular relation of all the quantities concerned that will give the best results, and yet, for a considerable variation either way, in submersion and air pressure, the quantity of water will remain the same.

The relation between the diameter of the discharge pipe and the velocity of water seems to be a delicate one. I should think that 5 feet per second would establish a good proportion. The air pipe must be large enough to minimize the friction loss.

The initial air pressure will, of course, be that due to the submersion, and will decrease after the discharge begins, until with a 3 to 2 submersion the pressure will correspond to a head of about one-half the submersion plus the lift.

In flowing artesian wells the best results seem to be obtained by giving deep submersion, small air quantity and high pressure.

Sand may be cleared from a well by filling the air reservoir with air at a high pressure, then suddenly releasing it, the air pipe having first been given quite a submersion. The sand comes out in masses and can be seen distinctly. In Fig. 19 one-half the column of water measured over 100 feet above the mouth of the well. It will be noted that about 20 feet above the mouth of the well the water seems to radiate in all directions from one center. It would seem that a bubble of compressed air had been carried up there and then suddenly expanded. The efficiency of the air lift naturally increases directly in proportion to the temperature of the water.

The air-lift has a special field of usefulness and will scarcely be given over to much competition with other pumps.

When a large quantity of water must be brought out of a small casing, no other method would be so satisfactory. If an artesian well fails to deliver to the proper point by a few feet, no other system could make it deliver its water so efficiently. For example, at Alvarado one of the large artesian wells refused by about two feet to flow into the general cachement basin. Nothing could be done but pump it, and this would require a centrifugal pump capable of handling 1000 gallons a minute to restore the required quantity. A one-inch compressed air pipe inserted 155 feet into the well, and consuming 6 horse power of compressed air, stimulated the well to complete action.

The plain open-air pipe seems to be the best means of ending the air pipe in the well and whether it point up or down is not

TABLE VI.

Head.	Quantity of Free Air.	Quantity of Water. Gallons.	Air P. in Receiving.	H. P. of Air.	H. P. of Work Performed.	Efficiency.	Submersion.	Ratio Air to Water.
39	170	750	37	20	8	40	60	1.7-1
30	150	400	20	11	3	27	45	-1
35	170	600	39	21	6	30	70	2.2-1
32	100	500	39	12	4	33	87	1.5-1
22	50	187	10	2	9	45	30	2

TABLE VII.

EXPERIMENT IN ARTESIAN AIR-LIFT PUMPING.

Depth of Well.	Size of Casing.	Natural Flow.	Height to Raise Casing to Stop Flow.	Submersion.	Quantity of Free Air.	Air Pressure.	H. P. to Beneath Air.	Pumping Head.	Quantity of Water Pumped. Gallons.	H. P. in Water.	Efficiency.	Ratio Air to Water.
950	5 & 8	200	6′	180	135	73	24	33	1300	11	46	0.8-1
950	5 & 8	200	6′	110	135	41	165	30	800	6	36	1.3-1
950	5 & 8	200	6′	146	135	56	20	32	900	7	35	1.2-1
700	7	20	1	100	120	38	16	30	800	6	38	1.2.1

TABLE VIII.

FOR AIR-LIFT PUMPING.

Diam. Air Cyl.	Stroke.	Cu. Ft. Free Air at 100 Revs.	Cu. Ft. Free Air at 125 Revs.	Suitable Pumping Heads.	Quantity Pumped at 100 Revs. in Gals.	Quantity Pumped at 126 Revs.	H. P. Required 100 Revs.	H. P. Required 125 Revs.	Ratio of Submersion to Lift.
60 to 100 Lbs. Pressure.									
10	12	92	108	80-120	200-175	232-205	12-17	15-20	3-2
12	15	165	195	80-120	350-310	420-370	22-32	26-36	3-2
14	16	245	288	80-120	525-465	620-550	35-45	38-55	3-2
30 to 60 Lbs. Pressure.									
12	12	132	152	40-80	330-285	380-325	12-18	14-20	3-2
14	15	229	270	40-80	570-500	675-580	22-30	25-35	3-2
16	16	312	368	40-80	780-670	920-800	30-40	35-50	3-2
10 to 30 Lbs. Pressure.									
14	12	183	216	10-40	640-450	850-540	8-18	10-22	3-2

material. Dividing the air into minute bubbles by fine perforations seems not to do as well as the open pipe.

I have compounded the air-lift into several lifts, one discharging into the other, with fair results, but it would be better to discharge each section into an open tank and let the water dispose of its air bubbles.

The greatest general efficiency of the system will become apparent under conditions where the number of wells that can be operated by an engine plant do not yield enough water without lowering the surface of the water too far. Let us say that normally the water stands at 20 feet from the ground, and, in order to get the quantity from six wells, they are lowered to 80 feet by sinking perhaps six more wells some greater distance away, and all twelve are worked with the air-lift. The pumping may be done at a head

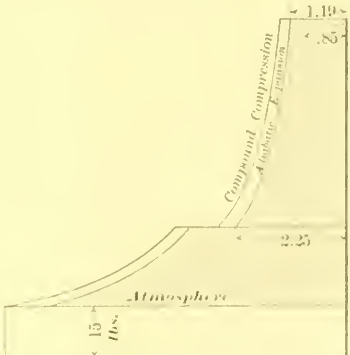

FIG. 20. DIAGRAM OF COMPOUND DOUBLE REHEATED AIR MOTOR FOR PUMPING.

of only 40 feet. This would be possible, of course, with pumps, but not practical.

In general, and within pumping limits of 120 feet, I shall conclude that from 50 to 60 per cent. efficiency is possible, but 30 to 40 per cent. will probably more nearly represent the average plant.

Tables VI and VII give the results of experiments made last year, and Table VIII gives some general requirements for air-lift pumping.

MOTOR-OPERATED PUMPS.

This class consists of pumps belted, geared or direct connected to engines of all kinds. There is no doubt that, with Corliss engines, coupled directly to pumps, the mechanical efficiency is as high as 85 per cent. Let us take an example on this basis, using compound compression, with engines cross-compound and double reheated to 300°, or $\frac{7}{5}$ increase of volume.

The comparison of curve areas, Fig. 20, shows that an efficiency of 88 per cent. should be obtained. This, it must be understood, is for a station pump, where all proportions are specially designed for the one object in view. In my calculations no account is taken of reheating. The expense is small, and I should think might be taken as 5 per cent. of the economy, consequently this sum should be deducted from all of my reheating calculations. It costs practically the same to heat to 300° or 400° as to 200°, provided the reheater is close to the motor, as it should be. The amount of air required by engines per horse power will vary from 25 to 5 cubic feet per minute of free air, according to the amount of reheating and the amount of expansion used.

TABLE IX.

RECAPITULATION.

90 Lbs. Air Pressure on Main.

KIND OF PUMP.	Foot-Gallons.	Efficiency, Simple Compound.	Efficiency, Compound.
Direct-Acting Simple	135	19	20
" " " 300 reheated	180	24	28
" " Compound Water reheated	232	32	375
" " " 1 cylinder heated 300	280	40	46
" " " 2 " " 300	326	46	53
" " Triple 3 " " 300	383	54	62
" " " 3 " " 400	444	63	72
Plain Displacement	175	22	25
Wheeler "	34% for 34 lbs. pressure		
Multiple "	320	40	46
Harris "		60 to 70%	
Merrill "	175	22	25
Cumming System		35 to 70%	
Compound Motor Pumps		50 to 80%	
Direct-Acting Triple Water heated	300	42	48
Pohlé Air-Lift	30 to 60% heads less than 200 ft.		

The loss in the compressed air problem is one of heat. The air is all there; none of it gets away. If this heat be restored and a sufficient quantity added to overcome leakage and clearance, we shall get back our original expenditure, of course, less the mechanical losses in the motor. Inasmuch as, in compound compression to 90 pounds, the temperature need not at any time exceed 225°, what is there to hinder our returning this and much more besides, when we have 500° at our service? I have used 430° in a Corliss motor, with excellent results, and I believe another 100° could have been added. The whole question is one of temperature, and the successful solution lies in special and intelligent adaptation of the forces at our service.

Too many have condemned compressed air without proper hearing, and I hope these remarks may stimulate some one to give special attention to the pump problem and give us some pumps worthy of the atmosphere which they now so generously use.

In conclusion it may be stated that I do not wish to be understood as giving absolute values to the quantities mentioned in this paper. Others may find in their experience that I have allowed too little or too much for mechanical efficiencies, or that I have assumed too high a standard pressure. This does not interfere with the comparative values of the various systems, which is the real point toward which I have desired to direct your attention.

For Figs. 2, 3 and 4, and accompanying notes, see pages 214, 215 and 216.

THE COMPOUND DIRECT AIR-PRESSURE PUMP WITH ADJUSTING RECEIVER.

Computations for Proportioning the Parts and a Graphical Presentation of one Cycle of Operation.

The Problem.—Proportion a system to lift 66 cu. ft. (500 gals.) per minute 200 feet in the lower stage, and 650 gals. (87 cu. ft.) per minute 175 feet in the upper stage, assuming lengths of air pipes to be 500 feet to lower and 300 feet to upper tanks.

Note.—In the following computations it is assumed that no change in temperature occurs and friction of air and of water in pipes is neglected.

Solution—Horse Power.—From figures given above the average net horse power = 55. But the max. rate of work per stroke is 10,900 ft.-lbs. (See ordinate at K, Fig. 3.) Assuming the compressor to work at 90 revolutions (or 3 strokes per sec.) this will give about 60 H. P.

Air Pipes.—If the volume of compressor stroke is previously known the max. velocity in air pipe of known area can be found by observing that immediately after switching the whole volume of compressor stroke goes through the air pipes.

Otherwise an approximate rate is: The max. air volume = 6 times the average water volume discharge. In this case the rule gives 5.5 cu. ft. per sec. of air at 102″. Hence select air pipes 4″ diam.

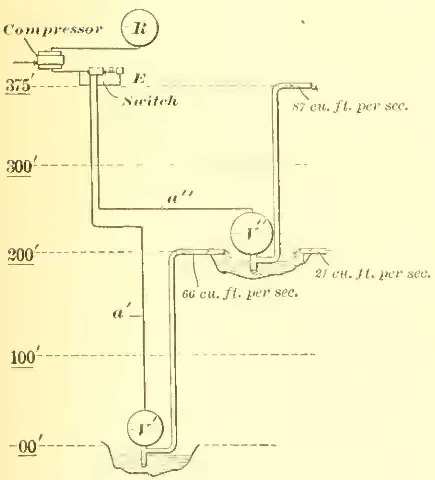

Fig. 2.

Tanks.—They should not be less than 10 times the vol. of air pipe. Hence assume V′ = 450 cu. ft. Then if no receiver were attached V″ would be computed by Eq. I, which would give V″ = 525; but by conditions of the problem, V″ must be = 1.3 V′ = 585. This requirement can be satisfied by attaching a receiver whose volume will be computed by Eq. II, whence R = 497.

In practice make V″ and R larger to permit adjusting, which can be done by pumping water in or out of R.

Notes on the Operation.

When air is switched out of V″ it expands into pipe a′, and thereby drops from 91″ to 88″ (G″ to A), then compressor forces air into V′, but no water will be delivered until pressure in V′ reaches 102. In the meantime pressure in V″ will be worked down to 76.5, which will require 47 strokes. (See A to B′ and A to B″.)

When air is switched out at V′ we will have V′ + R + a′ at 102″, while only 91″ is necessary to force water out of V″. Hence water will discharge without further action of compressor until all pressures drop to 91″. The volume of water thus displaced will be 96 cu. ft. This cannot be properly shown on the diagram. It occurs between D‴ and E‴, but as these points are coincident in time the effect will be to run the delivery curve up as shown in the dotted line near E‴.

Formulas III and IV do not apply after Pn falls below atmospheric pressure, for V′ (or V″) is then a variable. Hence the broken lines between C and D and F and G are not computed.

The two lines in each pair of heavy verticals S″ S″ and S′ S′ are coincident in time. The intervening space is for convenience in showing connections between curves.

SYMBOLS AND NUMERICAL VALUES.

— Absolute max. pressure in lower tank.
— " " " " upper "
and p″ = Absolute min. pressure in either tank.
= Volume of air pipe to lower tank.
— " " " " " upper "
— " " lower tank.
— " " upper "
— " " receiver.
— " " compressor stroke.
— Number of compressor strokes.
— Variable pressure in tanks.
— " work per stroke.
— " water volume delivered per stroke.

FORMULAS.

$$V'' = \frac{P' (V' + a') + p'' a'' - p' a'}{P''} - a'' \text{.......... I}$$

$$R = \frac{P'' (V'' + a'') - P' (V' + a') + p' a' - p'' a''}{P' - P''} \text{ II}$$

$$Pn = Po \left(\frac{V + a}{V + a + v} \right)^{n} \text{...................... III}$$

Po = initial pressure, Pn = that after n strokes.

$$n = \frac{\log. Po - \log. Pn}{\log. (V + a + v) - \log. (V + a)} \text{ IV}$$

$$Wx = Px\ V \log. \frac{Po}{Px} \text{................. V}$$

$$Vx = \frac{Px}{P'}\ v \text{...................... VI}$$

The proper value for v is found by trial in Eq. IV.

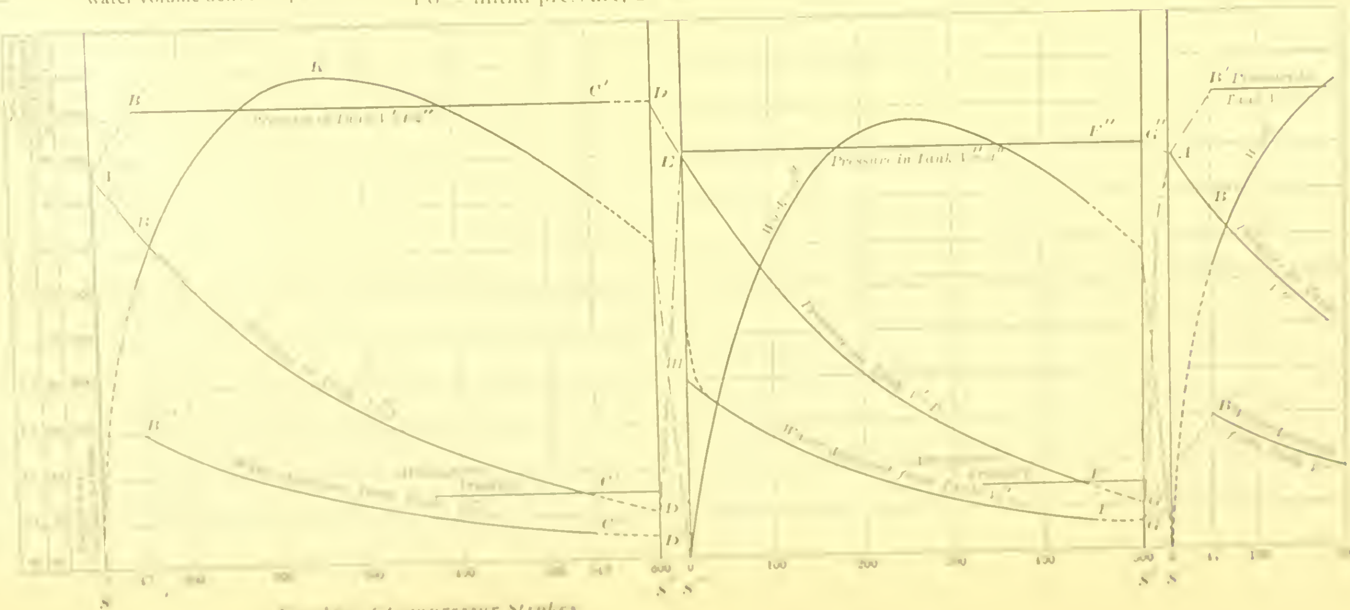

FIG. 3

SHEET No. 12.

The Compound Direct Air-Pressure Pump.

Diagrammatic Presentation No. 1. Pump applied to a single source with single lift.

Diagrammatic Presentation No. 2. Pump applied to wells in groups.

Diagrammatic Presentation No. 3. Pump applied in a "two-stage" lift.

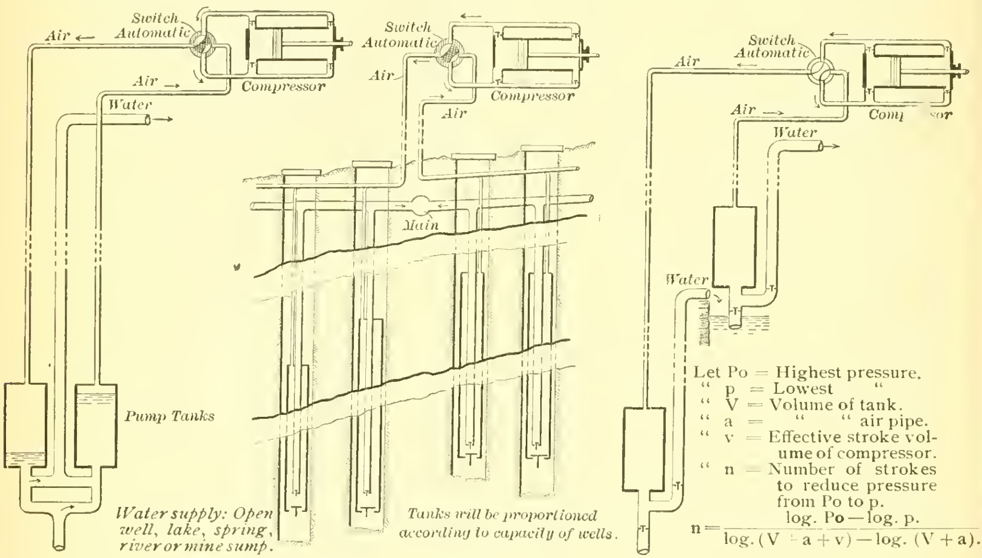

FIG. 4.

Notes on Operation.

One tank (or group of tanks) is emptied by air pressure while the other is drawn full by suction, the air charge being so adjusted that one tank is drawn full of water just when the other is emptied.

The switch can be automatically operated in either of three ways:

1. By means of the suction in the intake to compressor, which depends on the height to which water must be drawn in filling the tanks.

2. By a mechanism that will throw the switch at a given number of compressor strokes, the number required being that which will empty one tank and fill the other.

3. By an electrically controlled mechanism, the circuit being controlled either by floats in the pump tanks or by a pressure gage on the intake pipe.

Advantages.

1. The expansive energy in the compressed air is fully utilized.

2. There are no moving or delicate parts outside the compressor room, except the check valves on water pipes.

3. One compressor can pump water from any number of sources.

4. In mine drainage the tanks may be submerged to any depth.

WILLIAM GIDDINGS CURTIS.

Member, Technical Society of the Pacific Coast.

NOTICE.

The Experimental Filter Plant at Pittsburg.

In publishing this paper in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for November, 1900, the statement should have been made that the author, Mr. Morris Knowles, is a member of the

Boston Society of Civil Engineers,

and that the paper was read before that Society June 20, 1900. The omission of this statement arose from oversight in this office.

JOHN C. TRAUTWINE, JR., *Secretary.*

Editors reprinting articles from this Journal are requested to credit not only the Journal, but also the Society before which such articles were read.

ASSOCIATION

OF

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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

THE EXPERIMENTAL FILTER PLANT AT PITTSBURGH.

BY MORRIS KNOWLES, C.E., ASSISTANT ENGINEER IN CHARGE OF TESTING STATION, IMPROVEMENT AND FILTRATION OF THE WATER SUPPLY, PHILADELPHIA. FORMERLY RESIDENT ENGINEER, FILTRATION COMMISSION, PITTSBURGH.

[Presented June 20, 1900.*]

GENERAL.

THE city of Pittsburgh has a population of about 320,000, of which about 235,000 are supplied by the municipal works, which pump water from the Allegheny River. The remaining 85,000 are supplied by private companies, and almost all of the water for these is pumped from the Monongahela River. We are interested at this time in the supply from the Allegheny alone; and the water from this river, in regard to turbidity, may be said to be midway between the streams of New England and those of the Ohio and Mississippi Valleys. It is occasionally very muddy, carrying large quantities of fine silt and clay. It is also polluted by sewage from many cities, towns and mining villages, together with considerable mine drainage at times.

In June, 1896, the City Councils authorized the appointment of a Filtration Commission, to be composed of the Mayor, the Presidents of the Councils and eight representative citizens, two of whom were to be physicians. This commission, to quote the substance of the resolution, was to investigate the character of the present water supply, the effect of filtration, the advisability of establishing a filtration plant, and furnish an estimate of constructing and maintaining the same; also to investigate the feasibility and advisability of seeking other sources of supply.

*Manuscript received October 27, 1900.—Secretary, Ass'n of Eng. Socs.

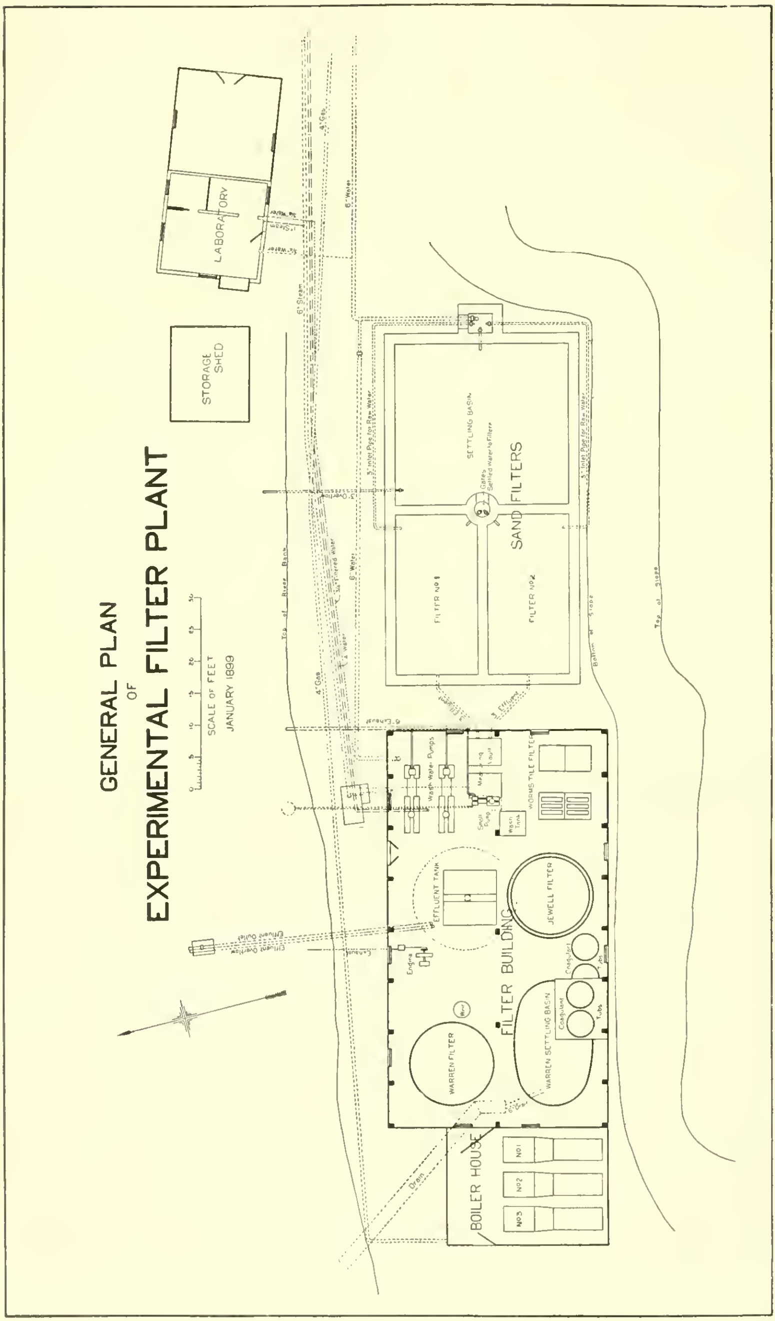

GENERAL PLAN
OF
EXPERIMENTAL FILTER PLANT
SCALE OF FEET
JANUARY 1899
LABORATORY
STORAGE SHED
SAND FILTERS
SETTLING BASIN
FILTER No 1
FILTER No 2
FILTER BUILDING
EFFLUENT TANK
JEWELL FILTER
WARREN FILTER
WARREN SETTLING BASIN
WORMS TILE FILTER
BOILER HOUSE
No 1
No 2
No 3

Fig. 1.

Mr. Robert Pitcairn, General Agent of the Pennsylvania Railroad, was Chairman of the Commission, and Mr. Allen Hazen, of New York city, was Consulting Engineer. Dr. Walther Riddle, of Pittsburgh, had charge of all chemical analyses, which were made in the private laboratory of Coster & Riddle. Mr. Wm. R. Copeland, formerly of the Experiment Station of the Massachusetts State Board of Health, at Lawrence, Mass., had charge of the bacteriological laboratory, located at the filter plant. He was also in direct charge of the operation of the experimental filters.

It is proposed in this paper to confine our attention to that portion of the investigations which was carried on at the experimental filter plant; to present a short description of the apparatus used, with views of some of the interesting details, and briefly to summarize some of the results obtained.

In May, 1897, preparations were made for beginning experiments with various types of filters, and upon July 23 the sand filters were placed in operation. Upon January 14, 1898, the mechanical filters were started. The tile filters were first started November 25, 1897, and again, after two months of idleness, upon June 12, 1898. The experiments were officially closed September 1, 1898, and the report of the Commission was transmitted to Councils in January, 1899.

DESCRIPTION.

The experimental filter plant was located at the pumping station of the municipal water works, at Brilliant Station, on the Allegheny Valley Railway, about six miles from city hall. Fig. 1 shows the general arrangement.

The plant consisted of two sand filter basins, with a settling basin about equal in area to both combined, a filter building, in which were located the measuring vault of the sand filters, the mechanical and tile filters, the filtered water tank, the wash water pumps and other machinery, also the experimental boilers (see page 000). Water was supplied to the plant from a large force main in the yard and was thus of about the same character as the river water, and changed nearly as rapidly as that in the river.

SAND FILTERS.

Description. A plan and vertical section of the two sand filters are shown in Fig. 2, together with a vertical section

*A report upon the whole subject, together with a semi-popular description of the experimental work and a discussion of the results will be found in "Report of Filtration Commission, Pittsburgh, 1899."

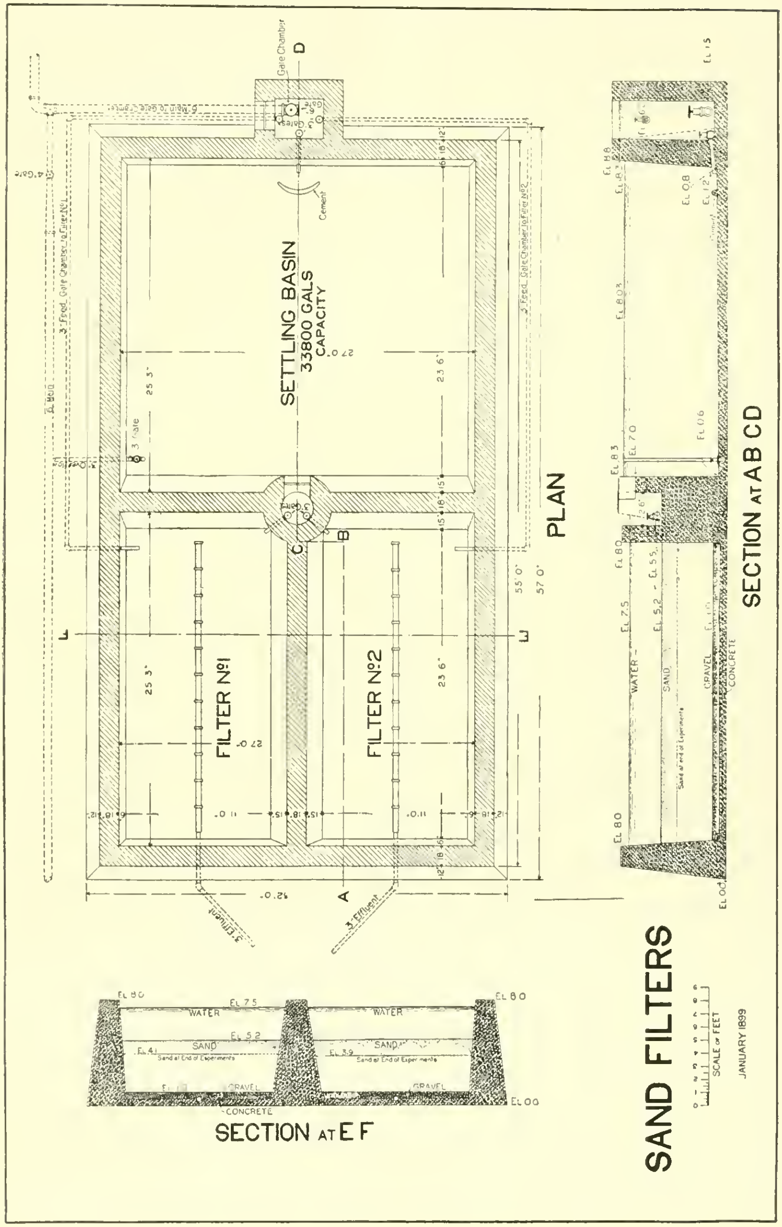


Fig. 2.

through Filter No. 2 and the settling basin. A view of them is given in Fig 3. The walls and bottom were built of concrete. The filters were not covered. The settling basin had a capacity

of about 33,800 gallons which, if complete displacement were realized, would have allowed twenty-four hours' sedimentation when one filter only was supplied with settled water. It is believed, however, that changes from inlet to outlet were accomplished in about two-thirds of this time. The average area of the sand surface was 0.0065 acre during the experiments, being about 12 square feet less at the close than at the beginning, owing to the batter of the walls.

The underdrain pipes were vitrified and 4 inches in diameter. Broken stone and gravel, to a depth of 6 inches, were placed on the concrete bottom and over the pipe. The layers of under-

FIG. 3. SAND FILTERS AND SETTLING BASIN.

draining material were as follows: Three inches of broken stone of about 3 to $2\frac{1}{2}$ inches in size, which was covered with screenings, or somewhat smaller broken chips, to close the larger interstices on top; $1\frac{3}{4}$ inches of clean river gravel of about $\frac{3}{4}$ to 5-16 inch in size; $1\frac{1}{4}$ inches of clean river gravel which had been passed through a 5-16-inch screen. Allegheny River sand, which was deposited loosely in six layers for a depth of 5 feet, completed the beds. After it had settled in water for a few days the thickness diminished to 4.2 feet, which was the amount in place at the beginning of the experiments. An average of 1.2 feet was removed during the thirteen months of operation. Fig. 4 shows the method of scraping and the care taken by the attendant, by

using sandals, not to make indentations in the sand surface. The average composition of the sand used may be seen in the following table:

RESULTS OF ANALYSES OF SANDS USED IN THE SAND FILTERS.

Source of Sample.	Effective Size (10% Finer than M. M.)	Uniformity Coefficient. Size (60% finer than) divided by Size (10% finer than)	Parts by Weight. Iron and Aluminum Oxides.	Calcium Carbonate.	Silicates and Insoluble Matter.
Filter No. 1.	0.30	2.0	0.98	1.32	97.70
" " 2.	0.31	2.0	0.96	1.35	97.69

FIG. 4. SAND FILTER, METHOD OF SCRAPING.

Apparatus. The effluent pipes were brought, side by side, into a small vault in the filter building, in which were placed the necessary devices for regulating and registering the quantity of water filtered. Meters were rendered unreliable by the amount of air carried in the water. Orifice indicators were therefore relied upon, and these had the additional advantage of indicating the rate of filtration at the instant of observation. Fig. 5 shows two views of one of these indicators. Ten standard orifices were drilled in the $\frac{1}{8}$-inch brass bottoms of copper cans 12 inches in diameter and 12 inches in depth. The water entered the side of the indicator and passed through a screen to prevent cross currents. On one side of the indicator was a glass slide, upon which a scale was fastened. The scale was graduated to read, upon one edge, in "Gallons per

Orifice, Daily," and, upon the other, in "Million Gallons per Acre, per Orifice, Daily."

The attendant was instructed to keep the water, on the latter scale, at the half-million rate mark as nearly as possible, so that half the number of orifices open corresponded approximately to the rate of filtration. Orifices not in use were closed with rubber stoppers. The loss of head was read downward directly upon a movable scaleboard, the zero of which was changed frequently during the day to agree with the level of the surface of the water outside on the filter basin. Various rates of filtration were used, between two million and five million gallons per acre daily, with both settled water and that which came directly from the river without any appreciable rest.

Fig. 5. Sand Filters, Orifice Indicator.

The turbidity of the river and settled waters was determined by observing the distance below the surface which a platinum wire could be seen in the water. The record was expressed as the reciprocal of the depth, in inches, at which the wire just disappeared from view. The turbidity of the effluents was observed by comparison, in gallon bottles, with standards of known turbidity, which were made from a stock silver nitrate solution, precipitated in distilled water with sodium chloride. The relation between the two standards was determined approximately, and all results were expressed in terms of the method first mentioned.

Results. The average quantitative and bacterial results secured with the sand filters during the thirteen months are given in the following table, No. 1. The figures given in this and subsequent tables are, in some instances, slightly different from those found in the report of the Filtration Commission. The difference is due to rounding up and using even figures.

TABLE No. 1.

AVERAGE OF DAILY RESULTS WITH SAND FILTERS, BY MONTHS.

Months.	Hours in Operation per Day.		Rates of Filtration, Million Gallons per Acre Daily.		Turbidity.				Bacteria per Cubic Centimeter.				Percentage of Bacteria Removed.	
					Raw Water.	Settled Water	Effluents.		Raw Water.	Settled Water.	Effluents.			
	No. 1.	No. 2.	No. 1.	No. 2.			No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
1897.														
August	23.8	22.9	2.40	2.30	0.18	0.13			2,090	1,280	46	42	97.80	97.99
September	24.0	24.0	2.98	3 00	0.05	0.04			2,480	1,230	16	16	99.35	99.35
October	23.3	23.7	2.90	2.95	0.03	0.03			72,900	39,200	32	32	99.96	99.96
November	21.5	20.1	2.64	2.42	0.26	0.18			25 200	29,900	346	632	98.63	97.49
December	22.4	23.5	2.76	2.46	0.19	0.14			14,400	14,900	163	225	98.87	98.44
1898.														
January	22.5	22.8	2.77	1.87	0.27	0.15			15,300	13,800	334	310	97.82	97.98
February	23.5	23.4	2.93	2.27	0.15	0.10	0.011	0.011	9,430	12,000	266	275	97.18	97.08
March	23.5	22.7	2.95	2.83	0.28	0.17	0.013	0.017	11,700	12,300	71	332	99.40	97.17
April	23.4	23.5	2.95	2.99	0.08	0.08	0.003	0.005	5 010	4,930	33	91	99.34	98.18
May	23.6	23 6	2.93	2.95	0.19	0.12	0.012	0.011	10,800	6,770	110	99	98.98	99.08
June	22.8	22.9	2.83	2.85	0.19	0.11	0.011	0.012	11,100	5,930	135	72	98.78	99.35
July	23.5	23.6	2.94	4.97	0.11	0.07	0.003	0.003	16,800	13,000	74	89	99 56	99.47
August	22.8	23.1	2.85	4.82	0.36	0.25	0.008	0.017	15,100	10,250	51	82	99.66	99.46
Average, 13 months	23.1	23.1	2.83	2.98	0.18	0.12	—	—	16,400	12,800	128	176	99.22	98.93

NOTES.—Filter No. 1 was operated with settled water all the time, except for occasional days

Filter No. 2 was operated with water not settled, but applied directly from the river, from July 24 to December 19, 1897, and from February 20 to June 30, 1898; and at other times with settled water.

Leaks and Cold Weather. In partial explanation of some of the relatively low bacterial efficiencies observed during the cold weather, attention should be called to the cracks in the wall between the settling basin and the filters, the effect of which first became noticeable in the effluents about the middle of November, 1897. At this time an effort was made to repair these cracks by closing them on the settling basin side, and it was then believed that this attempt was practically successful. In June, 1898, however, a small leak was again noticed. This time a small trough was built out under the opening, so that the water was compelled to pass out into the sand, instead of down along the wall. After this no trouble was noticed. Danger from cracks of this kind is lessened by placing the filter sand on the bottom for a short distance around the walls, instead of carrying the gravel and broken stone out close to the wall. But much safer, also, is that construction which places the settling basin at some distance from the filters, so that there is a barrier more efficient than a concrete wall between polluted and purified water. It is probable, however, that the lower bacterial efficiency in the winter was due in some degree to the disturbing influences of low temperature, especially upon the sand surface when exposed for scraping, upon these open and unprotected filters.

Recent Data. Through the kindness of the former Director of Public Works, Mr. E. M. Bigelow, M. Am. Soc. C. E.; the Superintendent of the Bureau of Water, Mr. A. B. Shepherd, and of Mr. Wm. R. Copeland, now Bacteriologist-in-charge, the writer is enabled to present, in Table No. 1 A, a summary of results obtained since September, 1898, by the Bureau of Water. The results for the winter months are in line with those in Table No. 1, and show markedly the influence of the cold weather.

In June, 1899, about one foot in depth of the top sand then remaining in the filters was removed, and new sand was placed in them to a depth of three feet; then about 9 inches of the old material was replaced, bringing the sand surface about to the original grade. For this reason the average results for the first six days of June, 1899, are reported separately from those for the last nineteen days. However, the average for the year 1899 was obtained by using an average for June, giving the proper weight to the duration in time of each group of results.

After August 23, 1899, five baffle walls were used in one half of the settling basin, causing the water applied to Filter No. 2 to travel in a horizontal tortuous course, and thus gave a more complete displacement.

TABLE No. 1 A.

Average of Daily Results with Sand Filters, by Months.
(After August, 1898.)

Months.	Hours in Operation per Day.		Rates of Filtration, Million Gallons per Acre Daily.		Turbidity.				Bacteria per Cubic Centimeter.				Percentage of Bacteria Removed.	
					Raw Water.	Settled Water.	Effluents.		Raw Water	Settled Water.	Effluents.			
	No. 1.	No. 2.	No. 1.	No. 2.			No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
1898.														
September	23.4	22.1	3.04	4.67	0.04	0.03	0.004	0.006	18,100	17,500	54	120	99.70	99.34
October	23.8	21.9	2.90	4.62	0.11	0.09	0.003	0.003	35,200	34,600	100	140	99.72	99.60
November	23.7	20.7	3.09	2.61	0.10	0.10	0.010	0.009	15,700	12,000	190	325	98.79	97.93
December	22.0	22.7	2.85	2.73	0.11	0.08	0.005	0.006	22,400	19,400	940	850	95.80	96.21
Average, 1898	23.2	22.7	2.92	3.35	0.17	0.11	0.008	0.009	15,700	13,600	197	233	98.75	98.58
1899.														
January	24.0	23.3	3.06	3.01	0.15	0.13	0.016	0.012	29,700	38,300	506	360	98.30	98.79
February	22.4	23.4	2.97	3.10	0.15	0.10	0.008	0.007	12,600	16,200	380	340	96.99	97.31
March	23.3	23.4	3.15	2.95	0.21	0.18	0.021	0.021	17,400	16 800	179	282	98.97	98.38
April	23.3	23.3	3.17	3.08	0.10	0.09	0.016	0.012	7,000	7,110	65	64	99.07	99.09
May	22.4	23.5	2.99	3.12	0.14	0.13	0.008	0.012	10,000	9,810	114	128	98.86	98.72
June—6 days	23.2	24.0	3.07	3.12	0.18	0.09	0.012	0.010	5,730	3,840	79	106	98.62	98.15
June—19 days	24.0	23.9	2.02	2 00	0.16	0.13	0.016	0.016	13,600	4 900	1500	1010	89.00	92.60
July	22.2	22.8	2.40	2.44	0.20	0.18	0.011	0.015	8,250	4,640	218	128	97.36	98.45
August	23.2	23.4	2.92	2.89	0.27	* 0.24 / 0.17	0.015	0.016	20,400	* 14,900 / 18 700	56	86	99.73	99.58
September	23.2	23.2	2.93	2.94	0.16	* 0.15 / 0.13	0.010	0.009	23,600	* 15,800 / 16,100	56	44	99.76	99.81
October	23.2	23.3	2.97	2.97	0.04	* 0.04 / 0.04	0.002	0.002	41 500	* 29,900 / 26,500	48	45	99.88	99.89
November	21.7	21.7	2.68	2.64	0.15	* 0.14 / 0.13	0.006	0.005	13,500	* 10,900 / 16,200	405	79	97.00	99.41
December	23.0	22.6	2.64	2.79	0.18	* 0.17 / 0.14	0.012	0.013	15,000	* 13,300 / 12,400	121	165	99.19	98.90
Average, 1899	23.0	23.1	2.85	2.84	0.16	0.13	0.012	0.012	17,600	15,400	272	207	98.45	98.82
January, 1900	21.7	21.1	2.44	2.34	0.19	* 0.14 / 0.13	0.012	0.014	22,100	* 27,800 / 21,400	463	535	97.9	97.58

Notes.—Settled water was applied to both filters all the time, except for occasional days.
Averages of both periods in June, and, for records starred, the average of both results, were used in computing yearly averages.
* First result given where starred refers to water applied to Filter No. 1, and second result to that applied to Filter No. 2.

Asbestos pulp was used on the surface of Filter No. 2 in different quantities from October 27 to November 12, 1898. From November 2 to December 13, 1898, sulphate of alumina was added to the applied water, as it entered the settling basin, at rates varying from ¼ to 1 grain per gallon. Neither of these special experiments was productive of conclusive evidence, as the time of trial was limited, and the facts are recorded here solely in order that the full history to accompany Table No. 1 A may be given. Fig. 6 shows how the asbestos pulp may be rolled up like a carpet when dried to the proper degree.

Fig. 6. Sand Filters. Removal of Asbestos Film

Periods between Scrapings. The following tables, No. 2 and No. 2 A, contain the results of the runs between scrapings, the first until September, 1898, and the second from that time to January, 1900. The results for Filter No. 1, in Table No. 2, differ slightly from the summaries given in the report of the Filtration Commission, as the figures have been entirely recalculated from the original records, to give the result at the exact time that the loss of head reached 4 feet:

Not all the periods have been included in Table 2 A. The records are omitted in cases where special tests with asbestos were conducted, and where, for experimental purposes, very small depths of sand were removed at a scraping, which created,

TABLE No. 2.

Quantitative Results Obtained during each Period of Operation with the Sand Filters, the Loss of Head Being Limited to Four Feet.

Number of Period.		Number of Days.		Average Turbidity.				Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet, Removed at Scraping.	
				Applied Water.		Effluent.					
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
1	2	22.8	14.7	0.19	0.27			44.6	30.8	0.04	0.04
2	3	45.7	37.1	0.06	0.06			135.9	111.3	0.06	0.04
3	4	32.9	37.0	0.03	0.04			98.8	111.8	0.05	0.06
4	5	17.9	4.2	0.20	0.54			53.1	12.1	0.05	0.07
—	6	—	11.0	—	0.24			—	32.7	—	0.09
5	7	18.2	21.4	0.15	0.16			54.1	51.0	0.13	0.05
6	8	12.1	17.0	0.07	0.18			36.0	34.1	0.03	0.04
7	9	12.1	9.4	0.21	0.14		0.022	35.9	18.6	0.05	0.10
8	10	11.2	29.1	0.10	1.10	0.012	0.011	33.1	69.1	0.10	0.06
9	11	30.5	18.6	0.10	0.13	0.012	0.009	91.3	56.8	0.07	0.06
10	12	26.4	4.2	0.21	0.98	0.014	0.046	79.8	12.3	0.12	0.13
—	13	—	14.4	—	0.14	—	0.013	—	43.8	—	0.07
11	14	32.8	26.4	0.06	0.08	0.002	0.002	99.2	81.1	0.07	0.07
12	15	33.3	23.8	0.10	0.21	0.014	0.015	100.2	72.1	0.07	0.10
—	16	—	16.1	—	0.22	—	0.008	—	48.4	—	0.11
13	17	30.0	17.2	0.12	0.15	0.007	0.013	90.4	69.3	0.09	0.06
14	18	30.8	22.5	0.21	0.07	0.003	0.001	92.8	114.4	0.13	0.07
—	19	—	17.7	—	0.28	—	0.012	—	89.5	—	0.12
Average.............		25.5	19.0	0.12	0.15	—	—	74.7	58.8	0.08	0.07

TABLE No. 2 A.

QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET.

(After August, 1898.)

Number of Period.		Number of Days.		Average Turbidity. Applied Water.		Average Turbidity. Effluent.		Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet, Removed at Scraping.	
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
16	20	29.8	22.3	0.05	0.09	0.006	0.018	72.3	112.3	0.05	[illegible]
17	21	30.0	33.8	0.06	0.03	0.001	0.002	71.7	179.1	0.09	0.09
18	——	19.8	——	0.10	——	0.014	——	64.0	——	0.07	——
19	27	10.2	13.4	0.05	0.04	0.004	0.000	33.9	41.0	0.10	0.24
20	28	16.2	13.4	0.04	0.09	0.000	0.002	51.2	41.2	0.09	[illegible]
21	——	9.9	——	0.20	——	0.016	——	30.7	——	0.15	——
22	29	34.1	28.1	0.12	0.14	0.013	0.014	100.6	86.6	0.11	0.17
23	30	12.3	27.3	0.05	0.06	0.005	0.006	39.4	84.1	0.09	0.08
24	31	39.1	30.2	0.20	0.21	0.022	0.019	96.3	94.0	0.24	0.12
25	32	31.3	36.1	0.11	0.12	0.020	0.016	98.5	100.7	0.09	[illegible]
26	33	23.2	38.2	0.04	0.10	0.005	0.011	76.3	121.8	0.04	[illegible]
27	——	15.0	——	0.11	——	0.011	——	18.4	——	0.04	——
28	34	[illegible]	16.1	0.10	0.16	0.012	0.015	38.3	37.8	0.05	[illegible]
29	35	17.0	[illegible]	0.14	0.17	0.012	0.010	48.0	[illegible]	[illegible]	[illegible]
30	36	[illegible]	23.0	0.21	0.23	0.016	[illegible]	70.1	[illegible]	[illegible]	[illegible]
31	37	[illegible]	[illegible]	[illegible]	0.12	0.012	[illegible]	[illegible]	[illegible]	0.11	[illegible]
32	38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	118.2	[illegible]	[illegible]	[illegible]
[illegible]	39	[illegible]	[illegible]	0.12	0.13	[illegible]	0.001	[illegible]	[illegible]	[illegible]	[illegible]
34	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	41	[illegible]	[illegible]	[illegible]	0.12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average	——	[illegible]	[illegible]	0.11	0.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

for the next run, a large initial loss of head, greater than one foot.

In Tables No. 2 and No. 2 A, it will be noticed that there appears to be some relation between the length of period, or

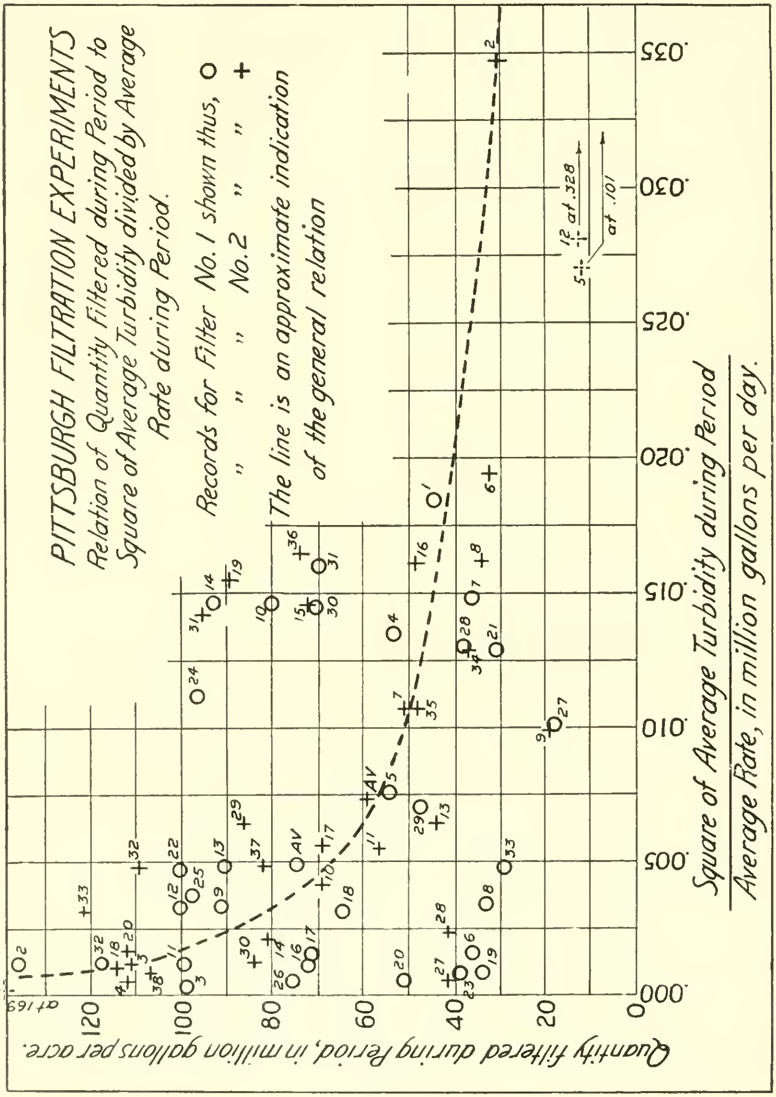


Fig. 7.

quantity filtered between scrapings, and the average turbidity for the period. In general, the more turbid the water the less the length of the period and the less the quantity filtered, but the relation is not an exact one. In Fig. 7 the results in Tables No.

2 and No. 2 A have been plotted, using, as ordinates, the quantity filtered, and, as abscissæ, the square of the average turbidity during the period, divided by the average rate. It will be seen that many points are at some distance from the average line, yet there does seem to be some general relation.

It may be that the storage of suspended matter in the sand, as evidenced by the turbidity of the effluent long after the muddy water has passed by, affects the length of the period to some degree. No doubt the length of the period is also somewhat affected by the variation in the temperature of the applied water; the low temperature in winter requiring a greater loss of head than the warm weather to filter the same quantity. It is probable, however, that these factors are obscured by the errors in determining the effect of the water upon the filters, in regard to depositing a clogging layer, but, more than anything else, the diagram teaches us that a more accurate method of observing turbidity is needed.

The question of this relation is an interesting and even an important one; for if, by continuous and systematic observations of the turbidity of a source of supply, the probable quantity of water that will be filtered between scrapings can be determined, the largest item of the cost of maintenance of slow sand filters may be accurately estimated without waiting for the actual trial of the filters.

TABLE No. 3.

AVERAGE RESULTS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM THE ALLEGHENY RIVER AND SAND FILTERS DURING THE THIRTEEN MONTHS ENDING AUGUST 31, 1898.

(Parts per 100,000.)

CONSTITUENTS.	River Water.	Outlet from Settling Basin.	Effluents.		Percentage of Constituents Removed.	
			No. 1.	No. 2.	No. 1.	No. 2.
Color	0.29	0.27	0.00	0.00	[illegible]	[illegible]
Nitrogen, as						—
Albuminoid ammonia	0.0116	0.0108	0.0063	0.0064	[illegible]	45
Free ammonia	0.0019	0.0019	0.0016	0.0016	16	16
Nitrites	0.0000	0.0000	0.0000	0.0000	—	—
Nitrates	0.0684	0.0641	0.0715	0.0647	5	5
Chlorine	2.19	2.08	2.06	2.02	6	8
Total solids	15.9	13.1	12.1	12.1	24	[illegible]
Suspended matter	4.2	1.3	0.0	0.0	100	100
Total hardness	3.58	3.00	4.72	4.83	—32	—35
Alkalinity	2.80	3.07	4.13	4.22	—43	[illegible]
Sulphuric acid	1.44	1.38	1.44	1.44	—	—
Iron	0.052	[illegible]	0.010	0.018	[illegible]	65

Chemical Results. Table No. 3 gives the average results, for the whole period, of the chemical analyses of samples of water collected (1) from the Allegheny River, (2) from the outlet from the settling basin and (3) from the sand filter effluents; together with the percentage of chemical constituents removed. Tables 12 A to 12 E, at the end of this paper, contain the monthly averages of the results of the chemical analyses and the average summaries for different periods.

WARREN FILTER.

This filter was located in the western portion of the filter building. A plan will be found in Fig. 8, and an elevation in Fig. 9. The system consisted of a settling basin, having baffle walls and a circular tank, or filter proper, which contained the filter sand and the agitating, washing and regulating devices.

Settling Basin. The capacity of the settling basin was about 11,200 gallons, which gave, if complete displacement were accomplished, a period of about fifty minutes for the water to pass from one end to the other when the filter was operated at a rate of 120,000,000 gallons per acre daily. Just before the water entered the settling basin it was measured by a meter, and then, at the entrance, was controlled by a butterfly valve, which was attached to a float on the surface of the basin. Next the water passed through a propeller, which operated the revolving coagulant pump or tympanum on the platform above.

Coagulant. The solution of coagulant was introduced as the water passed the propeller. The average composition of the sulphate of alumina, which was the coagulant used in both the Warren and the Jewell Filters, was:

	Parts of Weight.
Alumina oxide, soluble in water	17.18
Sulphuric acid	38.66
Iron oxide	0.00
Material insoluble in water	0.24

The coagulant solution was dissolved in two tubs, placed on top of the settling basin and was allowed to flow, first from one and then from the other, into the tank in which the tympanum was placed. The inner end of each arm of this pump was connected to one of a series of six tubes placed in the hub and parallel to the shaft. As the pump revolved each arm in turn was filled. As the arm became elevated the solution passed down into the hub, out into a lead cup on the side of the tank and thence to the settling basin below.

The elevation of the solution in the pump tank was kept as nearly constant as possible by rubber float valves. It was found, however, that this method was not entirely satisfactory, as the rub-

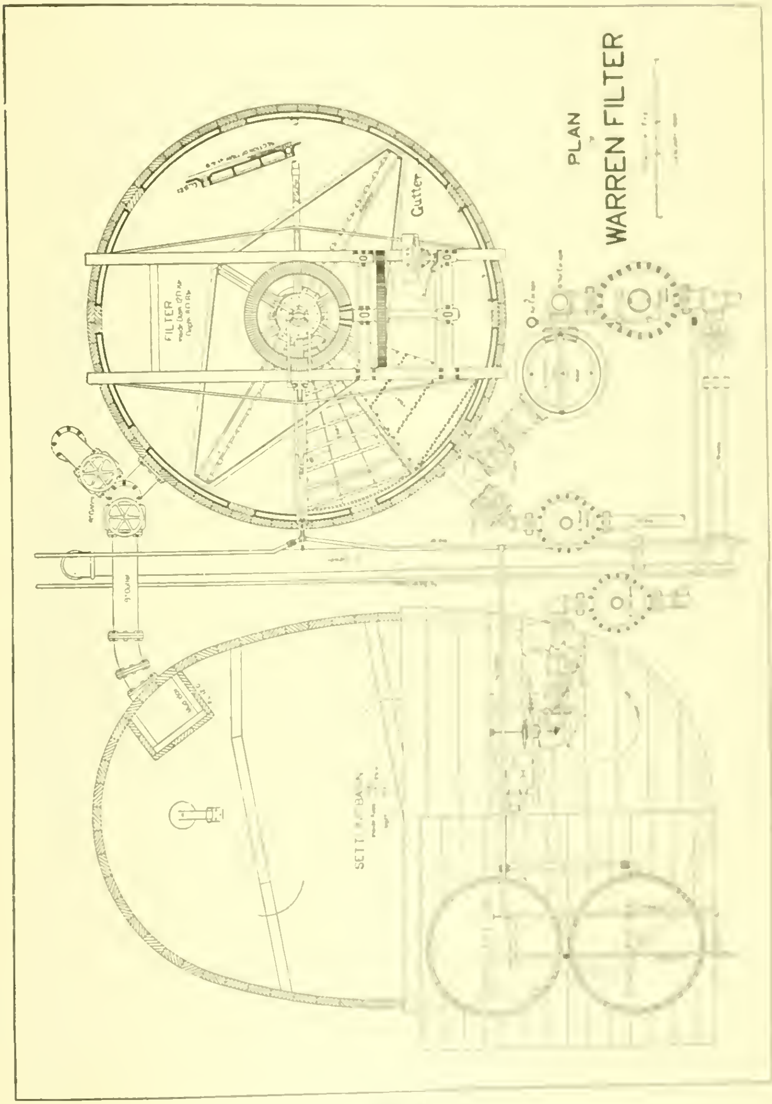


Fig. 8

ber valves frequently became clogged. Also, when a new solution was first used the higher elevation of the liquid in the pump tank, due to the pressure from a full tub above, caused much more coagulant to be added to the applied water than when the solution in the

upper tub had nearly run out. It was endeavored to remedy this by opening the valve from the coagulant storage tub a little only at the

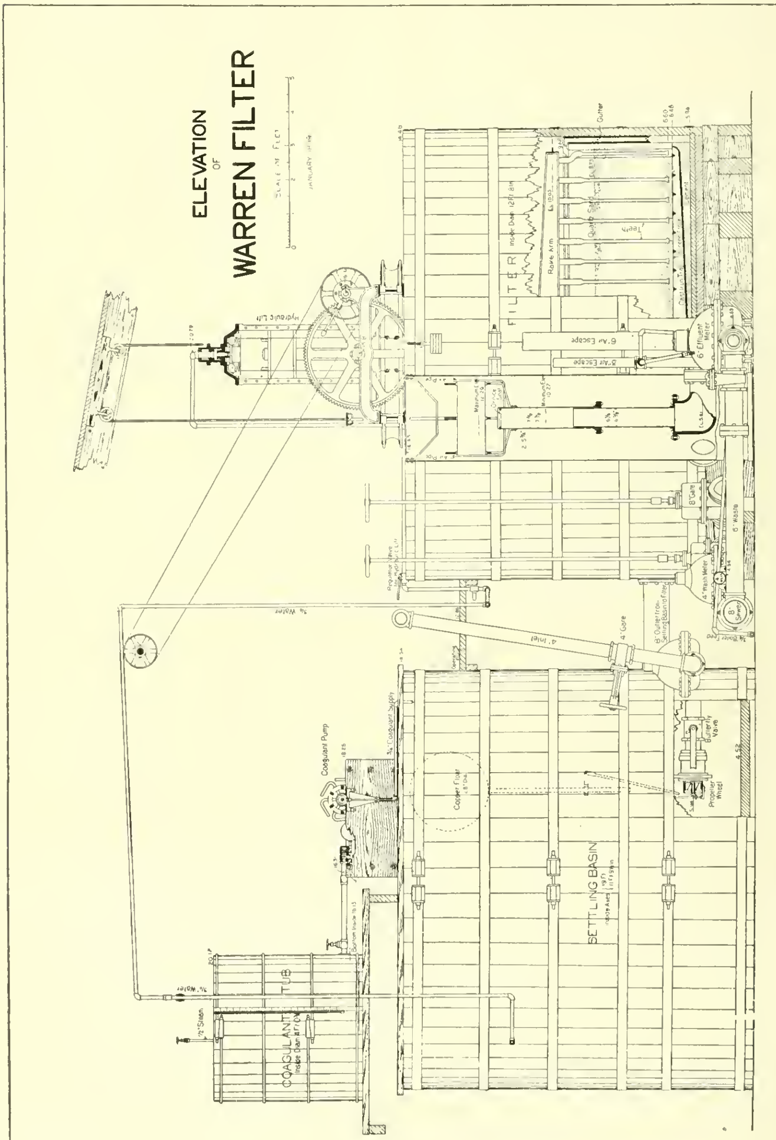


FIG. 9.

beginning, and gradually increasing this opening as the tub became empty. Even with this care, the rate of application of the coagulant solution was not constant.

Without quoting in detail the tables which are published in the report, the following brief summary, contained in Table No. 4, will show the nature and amount of this variation, both for the Warren and Jewell Filters. It must be remembered, however, in studying this table that it is more difficult to apply a coagulating liquid accurately on a small than on a large scale.

Filter. The filter proper was composed of a circular tank with a sand area of 118 square feet. On the bottom, inside, were placed segmental iron troughs set in concrete, which served as a support for a brass strainer floor and also as collectors for the filtered water. From the bottom of the tank, and connected directly with the inlet

FIG. 10. WARREN FILTER, DISMANTLED INTERIOR SHOWING CENTRAL WELL, SEGMENTAL TROUGHS, VERTICAL GUTTERS AND ONE 2-INCH CONNECTING PIPE

pipe, was a central well, which extended up through the filter floor and above the sand surface. Communicating with this well and passing between the collecting troughs were ten 2-inch horizontal pipes, which were connected with vertical iron gutters placed around the filter inside the staves.

The inlet water from the settling basin was distributed over the sand surface from the central well, and from the vertical circumferential gutters. Fig. 10 shows the central well, circumferential gutters and 2-inch connecting pipes, all at the time the filter was being dismantled.

The sand used was crushed quartz, which was angular at first, but the sharp edges became rounded after some months of use. The effective size was 0.63 mm., and the uniformity coefficient was 1.1. The sand was 2.3 feet deep, and rested directly on the brass strainer floor, which contained 292,900 holes, each being 0.024 inches in diameter.

Regulating Weir. After passing through the sand the water was collected in the radial troughs, and passed from a central annular compartment to the chamber of the so-called automatic weir. The principle of this device was that of a changeable orifice plate in a sliding pipe attached to a large copper float, and its object

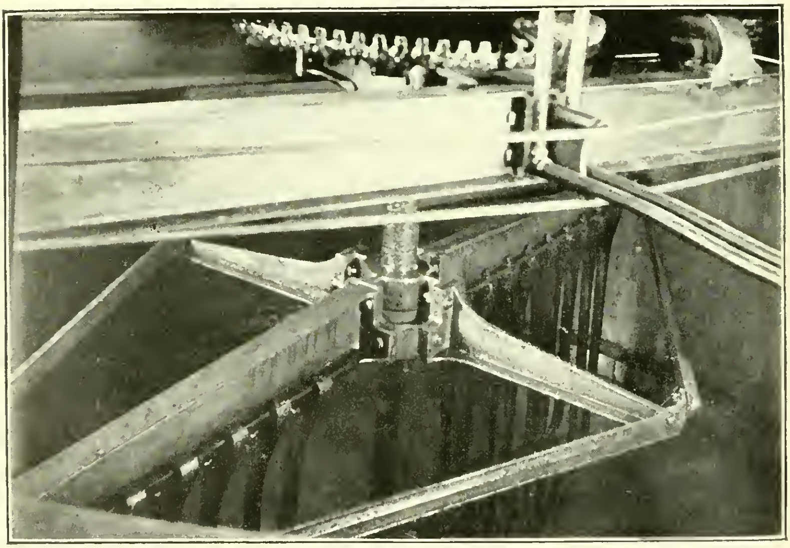


Fig. 11. Warren Filter, Agitating Device.

was to maintain the same head upon the orifice. In fact, however, the quantities filtered were somewhat less before washing than immediately after. The extent of the variation for some representative periods is given in Table No. 5. This controlling weir was the cause of overregistration of the effluent meter, due to the presence of air needed to operate the weir properly. This error was as large as 13 per cent., and varied in the beginning, but by the application of air escape pipes at proper places between the weir and the meter this error was reduced and maintained at 4 per cent.

Washing. Filtered water for washing was furnished by two duplex steam pumps, size 12 x 7 x 18 inches, which drew the water

from a large effluent tank under the building. The wash water was measured by a meter, then entered the filter by the effluent pipe and passed up through the screens and sand in the opposite direction to that of the current of water when filtering. As the dirty water flooded above the sand, it overflowed down the central well and the circumferential gutters, and thus passed out through a waste pipe to the sewer.

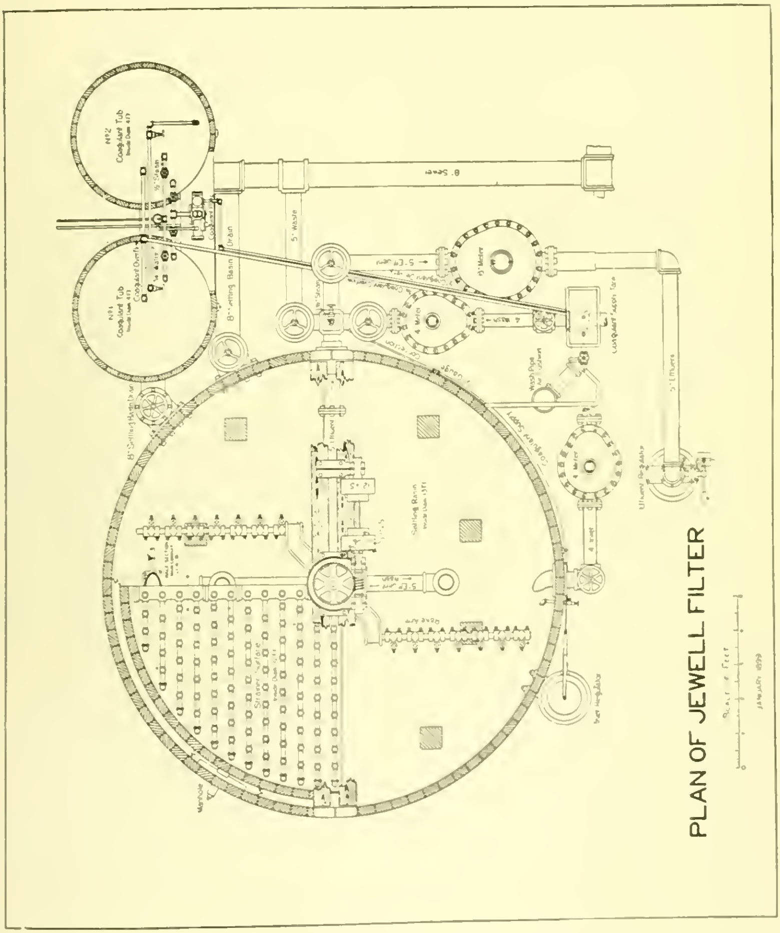


FIG. 12.

Agitator. At the time of washing the agitator was made to rotate through the sand at the rate of three turns to the minute, thus stirring the mass to the bottom. This device consisted of two horizontal arms, 180° apart, connected to a central vertical shaft, which was turned by gearing. The power in this case was furnished by a small engine on the floor. On each of the arms were

nine teeth, which cleared the strainer bottom by 0.14 feet when the agitator was in the lowest position. The device was raised and lowered by means of a hydraulic lift placed on top of the central shaft, the whole being supported upon I beams placed on top of the

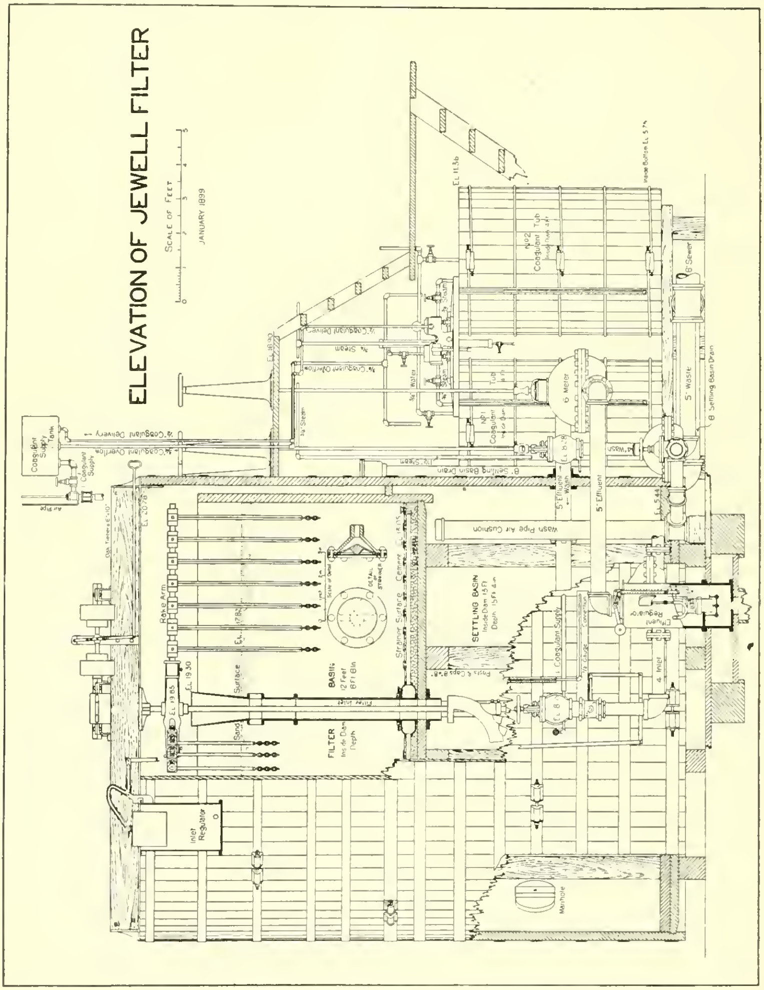


FIG. 13.

filter. Fig. 11 shows the rakes extending down from the arms and just touching the sand surface.

JEWELL FILTER.

This filter was located in the central portion of the filter building. A plan will be found in Fig. 12, and an elevation in Fig. 13. The plant consisted of a settling basin in the bottom portion of an

outside tank, and an open filter in a smaller tank placed within and above the former.

Settling Basin. The capacity of the basin was about 6600 gallons, which was equal to 35 minutes' flow when the filter was operated at the rate of 105,000,000 gallons per acre daily. The water was admitted to the basin through a curved deflecting pipe, which caused a whirling motion as it passed upward to the filter above.

Coagulant. The preparation of the coagulant was the same as for the Warren Filter. The solution was lifted by a small steam pump from either of the two tubs to a small tank above the filter, in which a constant head was maintained by pumping an excess and allowing the surplus to run back to the original tub. This method aided, somewhat, toward keeping the solution mixed in the tub. From the tank the solution passed through a standard orifice and pipe to the settling basin, which it entered near where the applied water passed in. Changes in the amount of coagulant supplied were made by changing the orifices. This method of application was somewhat more exact than that used with the Warren Filter, as the figures given in Table No. 4 indicate, but incrustation on the edges of the orifice changed the area and thus caused errors.

TABLE No. 4.

VARIATION IN THE APPLICATION OF COAGULANT TO MECHANICAL FILTERS.

Number of Experiment.	Calendar Date of Experiment, 1898.		Name of Filter.	Amount of Sulphate of Alumina Used, in Grains per Gallon. For Duration of Thirty Minutes. Highest.	Lowest.	Average for Duration of Experiment.	Percentage of Variation from the Average. Highest.	Lowest
1	April	14	Warren	0.91	0.30	0.55	66	—29
2	"	14	Jewell	0.53	0.20	0.34	56	—24
3	June	10	Warren	2.48	0.80	1.30	91	—38
4	"	23	"	3.96	0.66	2.19	81	—70
5	"	23	Jewell	2.48	1.05	1.90	31	—45
6	August	12	Warren	3.86	0.91	1.57	146	—42
7	"	12	Jewell	2.09	0.65	1.11	88	—41
Average				2.33	0.67	1.28	82	—48

Filter. The filter proper was placed above the settling basin, and contained 4.8 feet in depth of round-grained yellow beach sand, of an area of 113 square feet. Different sizes of sand were introduced by the company from time to time. The uniformity coefficient varied from 1.3 to 1.7, and the effective size from 0.33 mm. to 0.47 mm. The water from the settling basin passed up through a central well and overflowed the sand surface. After passing down through the sand the filtered water was collected in 443

screens, which were clamped over openings in the collecting pipes. The holes in the screens were 0.025 inches in diameter. Fig. 14 shows the screen heads on the pipes, together with the surrounding sand, over a portion of the bed. These pipes drained to collecting conduits which entered the 5-inch effluent pipe leading to the outside. Just outside the filter there was placed a cross connection, which allowed water to pass either through the effluent meter and regulator to a tank under the floor or to the sewer. This connection also permitted the introduction of wash water in a reverse direction for cleansing the filter.

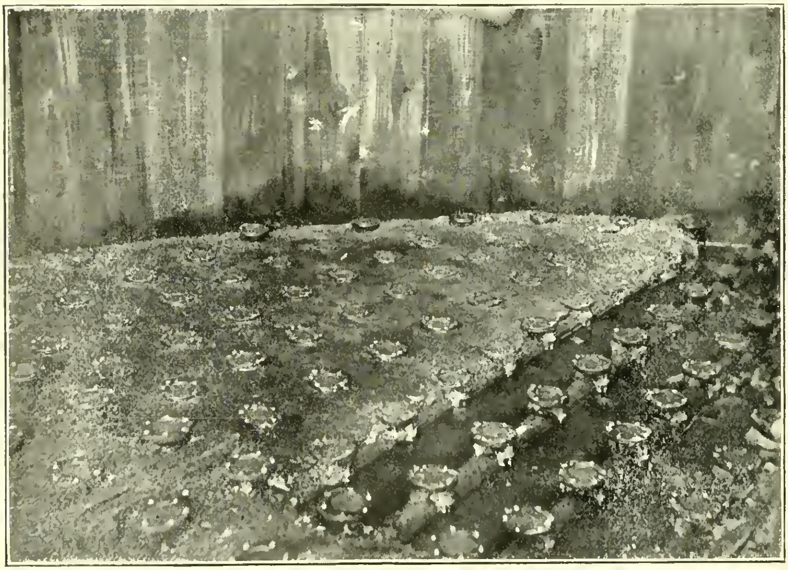


FIG. 14. JEWELL FILTER, SCREEN HEADS ON COLLECTING SYSTEM.

Controller. This device was intended to maintain a constant head upon an orifice plate placed in the bottom by allowing such water as rose above a certain level to flow over into a cup. This cup was attached to a lever arm, the inner end of which operated a butterfly valve in the pipe which discharged directly over this orifice. A view of the controller is given in Fig. 15. The efficiency of this device was tested from time to time, and the variations of the flow, as shown by representative tests, are given in Table No. 5. In this connection, however, reference should be made to a new form of controller recently devised for this use, which is said to give satisfactory results.*

*See paper by E. B. Weston, C.E., on "Mechanical Filtration," *Journal of New England Water Works Association*, June, 1900, page 343.

TABLE No. 5.

VARIATIONS IN THE RATES OF FILTRATION WITH MECHANICAL FILTERS.

Number of Experiment.	Calendar Date of Experiment, 1898.		Name of Filter.	Quantity Filtered, in Gallons.			Percentage of Variation.		
				For Duration of Thirty Minutes.		Average for Duration of Experiment.	From the Average.		Total between Extremes.
				Highest.	Lowest		Highest.	Lowest.	
1	April	14	Warren	8670	6380	7550	+15	—15	30
2	"	14	Jewell	6420	5210	5740	+12	—9	21
3	June	10	Warren	7720	4520	5780	34	—22	56
4	"	23	"	7110	5360	6330	+12	—15	27
5	"	23	Jewell	6290	5260	5780	+9	—9	18
6	August	12	Warren	9260	5170	7360	+26	—30	56
7	"	12	Jewell	8580	2680	5550	+55	—52	107
Average				7720	4940	6300	+23	—22	45

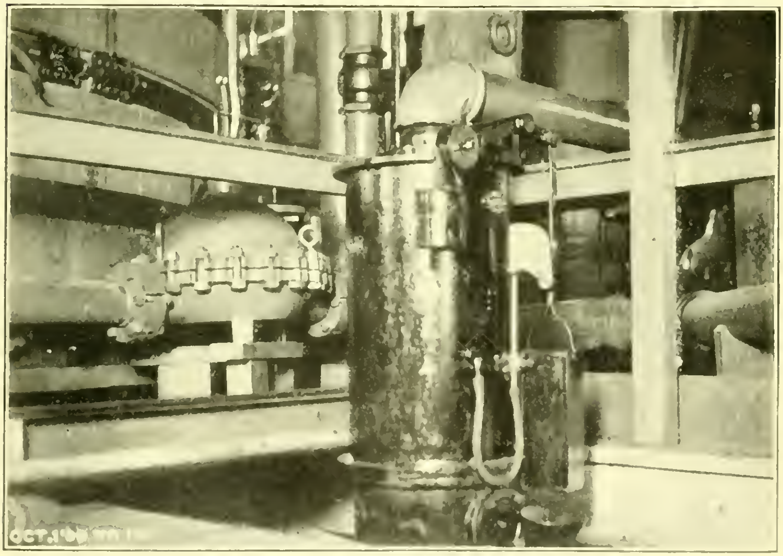


FIG. 15. JEWELL FILTER CONTROLLER.

Washing. This work was done in the same general manner as with the Warren filter, but in this case the dirty water overflowed into the annular space between the inner and outer tanks, and thus away to the sewer. The agitating device also was somewhat different. There were two sets of arms and rakes, the larger rakes being 4 feet long and fastened to arms reaching from the center across the filter bed and placed 180° apart. The shorter arms had only three rakes; were placed at right angles to the others, and stirred the sand close to the central well not disturbed by those on the longer arms. While the filters were operating these rakes lay

upon the sand of the filter, but when the power for agitating the bed was applied the arms started to revolve and forced the rakes to a vertical position and down into the sand. When the operation of washing was discontinued the arms were made to revolve in the opposite direction, and the rakes were thus trailed out on top of the bed again and left in a nearly horizontal position. The device made about seven turns per minute. Fig. 16 shows the rakes nearly pulled out to the surface of the sand.

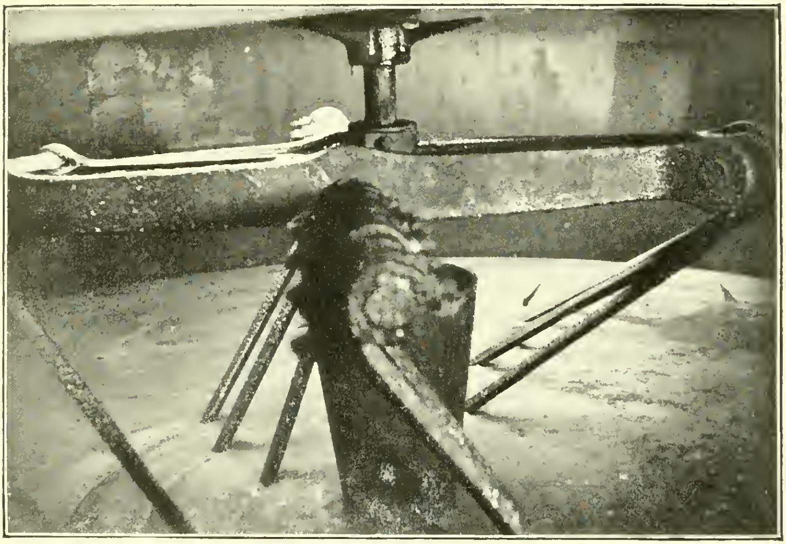


FIG. 16. JEWELL FILTER, AGITATING DEVICE.

At certain times, instead of washing the Jewell Filter bed, recourse was had to trailing the rakes around upon the surface of the bed in the direction opposite to that when washing, the water remaining upon the surface. This method made furrows about 2 inches deep in the sand. When the bed was new or had recently been thoroughly cleansed by the boiling solution of soda ash, this method was quite effective for once or twice after a washing, to restore the head lost and for lengthening the time between washings. But at other times its benefit was less evident.

MECHANICAL FILTERS IN GENERAL.

Effect of Washing. An interesting factor in mechanical filtration is the effect which washing the filter sand has on the character of the effluent. The results in Table No. 6 have been deduced from observations taken at random under the natural conditions of the

work of both filters. In general, the number of bacteria immediately after washing was about five times as great as before, and quite often the turbidity of the effluent was noticeably greater. It was observed that under normal conditions—that is, with applied water of about the average muddiness and using, directly after washing, the same amount of coagulant as was ordinarily used to

TABLE No. 6.

BACTERIAL EFFICIENCY WITH MECHANICAL FILTERS BEFORE AND AFTER WASHING.

Calendar Date, 1898.	Name of Filter.	Average Bacteria per Cubic Centimeter in Effluent. For Twenty-four Hours. Number.	For One Hour before Washing. Number.	For One Hour before Washing. Per Cent. of Average for Twenty-four Hours.	For Twenty Minutes after Washing. Number.	For Twenty Minutes after Washing. Per Cent. of Average for Twenty-four Hours.
March 31	Warren	69	32	46	326	473
April 1	"	69	54	78	271	393
" 1	"	220	294	134	387	176
April 2	Warren	220	126	57	444	202
" 14	"	79	73	92	160	203
" 19	Jewell	96	55	57	338	352
April 20	Warren	32	14	44	233	729
" 20	Jewell	96	59	61	329	353
" 21	Warren	6	4	67	38	633
April 23	Warren	15	8	53	52	347
" 24	"	15	51	340	47	313
May 3	Jewell	36	29	81	175	486
May 6	Jewell	28	6	21	205	732
June 2	Warren	105	79	75	516	491
" 2	"	100	60	60	469	469
June 6	Warren	17	6	35	21	124
August 12	"	165	11	7	1,180	715
" 13	"	165	166	101	549	333
Average....		85	63	74	319	375

secure good results—this poor condition of the effluent lasted about twenty minutes. If large quantities of coagulant were used directly after washing—that is, considerably more than the average amount necessary for good results with the given condition of the water—these higher numbers of bacteria obtained for a short time only, say five or ten minutes, after which they were greatly reduced.

Effects of Using Different Quantities of Coagulant. During the months of May and June, 1897, special experiments were made to determine the effect of using (1) large quantities of coagulant and (2) no coagulant.*

*For details, see "Report of Filtration Commission," pages 170, 171.

In general, after using a normal amount of coagulant the effect of not using any was apparent by a somewhat turbid effluent about forty-five minutes after shutting off the supply of coagulant. After two hours the number of bacteria was from one-half to about the same number as in the applied water, and the effluent was very much the same in appearance as the applied water. The time needed for a filter to recover itself after operation without coagulant, by using a large amount (in this particular case 2.75 grains per gallon), was also about two hours.

Whirling Motion. Mr. E. B. Weston, in his very interesting paper on "Mechanical Filtration," presented to the New England

TABLE No. 7.

EFFECT OF WHIRLING MOTION UPON SETTLING WITH COAGULATION.

Month, 1898.	Bacteria per Cubic Centimeter.		
	Applied Water.	Settled Water.	
		Warren.	Jewell.
February	9,430	7,130	7,190
March	11,750	6,160	5,780
April	5,000	3,360	3,620
July	16,800	10,900	10,900
August	15 100	7,550	7,780
Averages	11,600	7,020	7,050
Date, 1898.	**Amount of Suspended Matter. (Parts per 100,000.)**		
August 15	3 9	3.6	2.8
" 29	2.4	0 6	0.8
Averages	3.1	2 1	1.8
Ratio of Capacity of Settling Basin to Daily Quantity	--	0.0359	0.0244

Water Works Association, January 10, 1900,* has shown that by giving a whirling motion to the water entering the Jewell settling basin the precipitation of suspended and organic matter is considerably increased. So far as the writer knows, Table No. 7 gives the first published numerical data for cases where the same water was used, both with and without whirling. The quantities of coagulant added to the two filters are not sufficiently different to affect seriously the results and conclusions, but are, in general, larger for the Warren. It will be seen that the effect of the coagulation in each

*Journal of New England Water Works Association, for June, 1900, pages 349, 358, 359.

settling basin is about the same, although the Warren has 50 per cent. greater capacity in proportion to the daily quantity. In this settling basin the water takes a somewhat winding but quiet course, while in the Jewell it is given a rapid whirling motion.

The quantitative and bacterial results obtained with the mechanical filters, tabulated by months, are given in Table No. 8. The averages of the chemical constituents of the applied water and of the effluents of the mechanical filters, also compared with those of the sand filters for the same seven months, are given in Table No. 9.

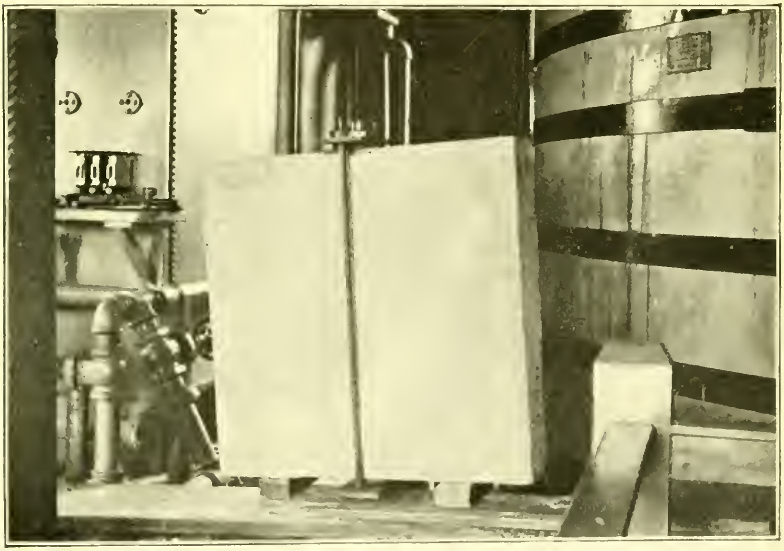


FIG. 17. WORMS TILE WITH FITTINGS.

WORMS TILE FILTER.

The process of water purification by the "Wormser" system, as tried at Pittsburgh, was two-fold: First a preliminary treatment by the addition of chloride of iron and removal of some matter by passage through broken stone, and, second, a filtration through the tiles.

Tiles. The tiles were made in Germany, and were composed of sand and broken glass baked in a mold. They were about 39 inches square and 4 inches thick. In the center of each there was a chamber of about $\frac{1}{3}$ cubic foot capacity, in which the water collected after filtering through the sides. Fig. 17 shows a view of a tile ready to be placed in the tank, and the method of making the pipe connection by gasket to the hole leading to the interior of the tile.

TABLE No. 8.

AVERAGE DAILY RESULTS OF MECHANICAL FILTERS BY MONTHS.

Months, 1898.	Hours in Operation per Day.		Rate of Filtration in Million Gallons per Acre Daily.		Ratio of Washing Time to Operating Time in Percentage.		Per Cent. of Filtrate Used in Washing.		Sulphate of Alumina, Grains per Gallon.		Turbidity.			Bacteria per Cubic Centimeters.			Percentage of Bacteria Removed.	
												Effluents.			Effluents.			
	Warren.	Jewell.	Warren.	Jewell.	Warren.	Jewell.	Warren.	Jewell.	Warren.	Jewell.	Applied Water.	Warren.	Jewell.	Applied Water.	Warren.	Jewell	Warren.	Jewell.
January	10.1	8.1	117	85	2.3	3.4	4.8	8.8	1.19	0.72	0.29 W. 0.16 J.	0.001	——	19,550 W. 12,950 J.	950	1980	95.14	84.70
February	21.3	20.7	104	98	1.4	2.1	3.8	6.1	0.70	0.56	0.15	0.005	0.004	9 430	238	638	97.48	93.23
March	22.3	22.2	108	106	0.9	1.2	3.5	4.3	1.81	1.07	0.30	0.001	0.001	11,750	164	208	98.60	98.23
April	23.0	22.9	122	106	0.7	0.7	2.6	2.8	0.86	0.54	0.08	0.001	0.000	5,000	78	159	98.44	96.83
May	23.6	23.2	115	106	0.8	1.2	2.6	4.6	1.55	1.00	0.19	0.015	0.000	10,800	630	150	94.20	98.61
June	23.3	22.8	103	106	1.0	1.4	3.9	5.4	1.36	1.18	0.19	0.001	0.008	11,100	115	1450	98.96	86.90
July	19.5	22.2	119	103	1.4	1.8	5.1	7.6	1.46	1.31	0.11	0.003	0.008	16,800	320	345	98.10	97.95
August	23.2	22.9	137	103	1.5	1.5	5.1	6.3	1.76	1.35	0.36	0.016	0.000	15,100	290	260	98.08	98.28
Average, 6 months	22.1	22.3	115	104	1.1	1.4	4.0	5.3	1.32	0.97	0.20	0.004	0.002	11,500	201	293	98.25	97.45

NOTE.—During the month of May with the Warren Filter and the month of June with the Jewell Filter, special experiments with varying quantities of coagulant were made. Averages do not include these months, nor the month of January.

TABLE No. 9.

AVERAGE RESULTS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM THE ALLEGHENY RIVER AND SAND AND MECHANICAL FILTERS DURING THE SEVEN MONTHS ENDING AUGUST 31, 1898.

(Parts per 100,000.)

Constituents.	River Water.	Effluents.				Percentage of Constituents Removed.			
		Sand Filters.		Mechanical Filters.		Sand Filters.		Mechanical Filters.	
		No. 1.	No. 2.	Warren.	Jewell.	No. 1.	No. 2.	Warren.	Jewell.
Turbidity		0.010	0.012	0.000	0.001	—	—	—	—
Color	0.26	0.07	0.07	0.03	0.03	73	73	88	88
Nitrogen, as–									
Albuminoid ammonia	0.0101	0.0054	0.0053	0.0047	0.0043	47	48	53	57
Free ammonia	0.0020	0.0018	0.0018	0.0019	0.0018	10	10	5	10
Nitrites	0.0000	0.0000	0.0000	0.0000	0.0000	—	—	—	—
Nitrates	0.0568	0.0642	0.0549	0.0550	0.0520	—13	3	3	8
Chlorine	1.87	1.84	1.77	1.76	1.65	2	5	6	12
Total solids	15.4	10.8	10.6	9.5	9.4	30	31	38	39
Suspended matter	5.3	0.0	0.0	0.1	0.1	100	100	98	98
Total hardness	3.21	4.31	4.33	2.96	2.89	—34	—35	8	10
Alkalinity	2.44	3.53	3.56	1.64	1.69	—45	—46	33	31
Sulphuric acid	1.15	1.15	1.15	1.86	1.59	—	—	—62	—38

Washing. The tiles were washed by a reverse current of filtered water, with a head of 19.5 feet above the centers of the tiles. In washing the tiles, care was taken to let on the wash water pressure slowly, and to maintain the flow uniformly. Nevertheless, as soon as the tiles became sufficiently clogged to produce a good effluent they all were broken, one after another, while being washed. Fig. 18 shows the line of breakage on two of the tiles, and gives an idea of the interior construction.

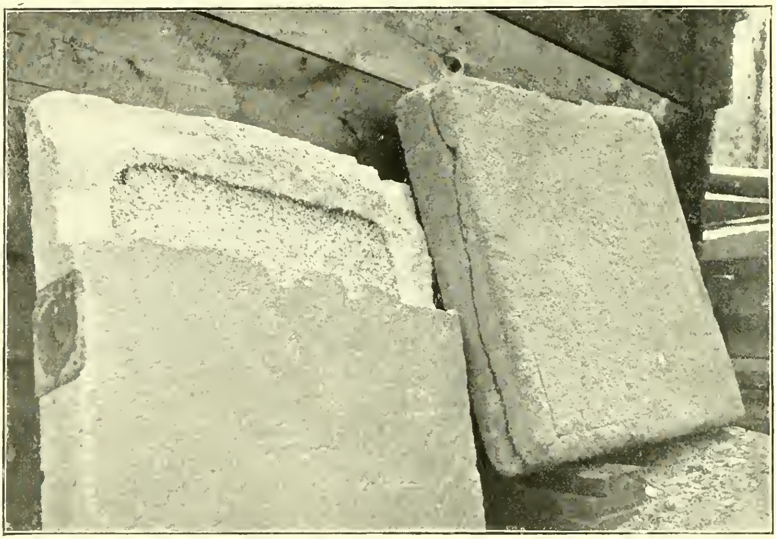


Fig. 18. Worms Tiles, Broken in Service.

Results. In Table No. 10 are presented the average bacterial results, by months, obtained with this system of filtration. It will be seen that the tiles themselves do not appear to have materially reduced the number of bacteria below those in the water flowing from the settling tanks, which had been treated with coagulant.

BOILER EXPERIMENTS.

The use of water for industrial purposes is an important consideration in Pittsburgh, or, indeed, in any large manufacturing city. It was therefore considered advisable to learn what the effect would be of clarifying and filtering the Allegheny River water prior to its use in boilers.

Three new 25 H. P. boilers were kindly loaned by the Oil Well Supply Company for the purpose of an experiment in this line. Boiler No. 1 was supplied with the effluent from the sand filters, No. 2 with the effluent from the mechanical filters and No. 3 with

TABLE No. 10.

AVERAGE BACTERIAL RESULTS WITH WORMS TILE FILTER.

Month, 1897–98.	Applied Water.	Bacteria per Cubic Centimeter. Settled Water. Tank No. 3.	Effluents. Tile A.	Tile B.	Tile C.	Settled Water. Tank No. 4.	Effluents. Tile D.	Tile E.	Tile F.	Percentage of Bacteria Removed. Settled Water. Tank No. 3.	Effluents. Tile A.	Tile B.	Tile C.	Settled Water. Tank No. 4.	Effluents. Tile D.	Tile E.	Tile F.
FIRST TEST.																	
December	14,430	9160	8010	5280	5960	12,260	4990	5430	4930	36.60	44.50	63.40	58.70	15.00	65.40	62.30	65.00
January	15,330	7680	3050	3360	2470	——	6550	4120	——	49.90	80.10	78.10	83.90	——	57.30	73.20	——
February	9,430	3290	740	800	1030	——	——	——	——	65.10	92.20	91.50	89.10	——	——	——	——
March	11,750	4700	460	630	790	——	——	——	——	59.20	96.00	94.60	93.30	——	——	——	——
SECOND TEST																	
June	12,000	339	690	470	500	410	510	470	470	97.20	94.30	96.10	95.80	96.60	95.70	96.10	96.10
July.............	16,800	920	310	400	370	1,010	980	900	590	94.50	98.20	97.00	97.80	94.00	94.20	94.30	96.50
August	16,900	345	100	120	70	360	340	320	110	98.00	99.40	99.30	99.60	97.80	98.00	98.10	99.40
FIRST TEST																	
Average ...	12,730	6230	3070	2520	2560	——	——	——	——	51.10	75.90	80.20	79.90	——	——	——	——
SECOND TEST																	
Average ...	15,200	535	360	330	310	600	610	580	390	96.50	97.60	97.80	97.90	96.10	96.00	96.10	97.40

NOTE.—Coagulant was applied to the water in Tank No. 3 all the time; but to the water in Tank No. 4 during June, July and August only.

the unclarified river water. When these boilers had been in service for about two and one-half months they were blown off hot. Samples of scale were collected, and an examination was made of the interior of each. The results of the chemical analyses of the scales are given in the following Table, No. 11:

TABLE No. 11.

Results of Chemical Analyses of Boiler Scale Samples, Collected September 17, 1898.

Items.	Parts by Weight.		
	Boiler and Sample Number.		
	1	2	3
	Water from Sand Filters.	Water from Mechanical Filters.	Water from River.
Calcium carbonate	53.21	27.42	3.34
Calcium sulphate	13.06	53.88	0.75
Magnesium carbonate	25.33	12.58	11.06
Sodium chloride	5.74	1.64	0.39
Iron and aluminum oxides	1.42	3.64	16.66
Insoluble matter	1.24	0.84	67.80
Totals	100.00	100.00	100.00

Scale. It will be seen that the scale from Boiler (No. 1), using the effluent from the sand filters, was composed largely of the carbonates of calcium and magnesium, which are not as troublesome as the sulphates. It was said that, by cooling down slowly, the formation of this kind of scale could have been, in a measure, prevented. It will be noticed, however, that the scale from Boiler (No. 2), using the effluent from the mechanical filters, was composed largely of sulphate of calcium, which is what would be expected from the chemical action caused by the addition of sulphate of alumina to the water. The scale upon Boiler (No. 3), using the unclarified river water, was soft, and composed largely of mud and insoluble matter, material which could have been largely removed by judicious blowing out from time to time.

The statement of the practical boiler mechanic who examined the interiors after the experimental use was that Boiler No. 3 was in the best condition. This problem, however, must be considered as by no means settled by such a limited experiment.

CHEMICAL ANALYSES.

On the next few pages will be found tables showing, by months, the average chemical results obtained from the river water and from the various effluents.

TABLE No. 12 A.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM ALLEGHENY RIVER AT BRILLIANT.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as Albuminoid Ammonia.	Nitrogen as Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
1897	June	—	0.0137	0.0006	0.0000	0.0175	2.40	14.1	—	7.65	—	1.40	—
"	July		0.0307	0.0034	0.0001	0.0106	3.13	26.9	11.1	5.84	6.08	1.33	0.184
"	August	—	0.0210	0.0023	0.0000	0.1050	2.03	9.0	1.0	5.41	4.05	0.86	0.007
"	September	0.37	0.0133	0.0010	0.0000	0.0650	2.70	13.1	—	5.03	4.63	1.82	0.063
1897	October	0.23	0.0120	0.0017	0.0000	0.0550	3.81	17.7	—	5.49	5.09	2.31	0.046
"	November	0.29	0.0152	0.0019	0.0000	0.0700	3.15	19.7	2.0	3.89	3.51	2.47	0.095
"	December	0.30	0.0111	0.0015	0.0000	0.1075	2.11	23.7	10.7	2.24	1.72	1.79	0.123
1898	January	0.28	0.0074	0.0016	0.0000	0.0885	1.53	15.3	4.8	2.09	1.48	1.43	0.112
"	February	0.21	0.0099	0.0020	0.0000	0.1425	1.46	11.9	1.4	2.59	1.73	1.24	0.059
"	March	0.24	0.0076	0.0015	0.0000	0.0487	1.29	14.0	4.3	2.72	1.75	1.18	0.040
1898	April	0.22	0.0077	0.0018	0.0000	0.0458	1.36	9.4	0.2	2.29	1.83	1.08	0.041
"	May	0.30	0.0104	0.0015	0.0000	0.0180	1.66	20.7	11.9	2.80	2.13	1.00	0.033
"	June	0.25	0.0085	0.0019	0.0000	0.0300	2.42	19.1	9.0	3.51	3.10	1.04	0.010
1898	July	0.27	0.01[illegible]	0.0027	0.0000	0.0694	2.47	13.1	1.4	4.53	3.41	1.55	0.020
"	August	0.31	0.0103	0.0024	0.0000	0.0435	2.42	19.5	8.8	3.99	3.15	0.93	0.020
Ave., 15 months		0.27	0.0130	0.0019	0.0000	0.0611	2.26	16.5	5.4	4.00	3.12	1.43	0.061
Ave., Aug., '97—Aug., '98		0.27	0.0116	0.0019	0.0000	0.0684	2.19	15.9	5.0	3.58	2.89	1.44	0.051
Ave., Jan., '98—Aug., '98		0.26	0.0097	0.0019	0.0000	0.0608	1.83	15.4	5.2	3.06	2.32	1.18	0.042

TABLE No. 12 B.

Average Results by Months of Chemical Analyses of Samples Collected from Gate Chamber.

(Parts per 100,000.)

Year	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897	July	——	0.0260	0.0020	0.0001	0.1481	1.12	15.0	6.0	4.39	4.71	1.07	0.185
"	August	0.45	0.0222	0.0015	0.0000	0.0763	1.63	14.1	4.3	5.44	5.13	1.10	0.177
"	September	0.32	0.0128	0.0017	0.0000	0.0471	2.47	13.3	——	5.75	4.95	1.86	0.044
1897	October	0.26	0.0141	0.0018	0.0000	0.0670	3.41	17.2	——	5.30	4.92	2.47	0.052
"	November	0.29	0.0148	0.0017	0.0000	0.0557	3.13	21.3	3.6	4.15	3.73	2.48	0.114
"	December	0.30	0.0085	0.0014	0.0000	0.1012	1.73	15.8	3.5	1.84	1.44	1.63	0.125
1898	January	0.26	0.0070	0.0012	0.0000	0.0915	1.37	14.4	4.6	2.11	1.60	1.37	0.118
"	February	0.24	0.0106	0.0014	0.0000	0.1400	1.29	12.7	2.4	2.80	1.86	1.15	0.116
"	March	0.23	0.0102	0.0030	0.0000	0.0495	1.18	22.2	12.0	2.88	1.91	1.66	0.064
1898	April	0.23	0.0083	0.0021	0.0000	0.0544	1.29	9.0	0.1	2.75	2.11	1.14	0.040
"	May	0.29	0.0116	0.0011	0.0000	0.0300	1.39	11.0	2.7	2.79	2.19	0.74	0.042
"	June	0.25	0.0089	0.0022	0.0000	0.0394	2.16	17.8	7.7	3.34	3.15	1.13	0.013
1898	July	0.26	0.0098	0.0028	0.0000	0.0694	2.44	12.7	0.9	4.56	3.47	1.36	0.022
"	August	0.29	0.0107	0.0025	0.0000	0.0450	2.35	19.7	8.6	4.03	3.16	1.01	0.016
Average, excluding July, '97		0.28	0.0115	0.0019	0.0000	0.0667	1.99	15.5	4.6	3.67	3.05	1.47	0.073

TABLE No. 12 C.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SETTLING BASIN.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hard-Less.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897	July	——	0.0234	0.0031	0.0000	0.1075	1.70	14.0	5.5	4.73	6.05	1.44	0.147
"	August	0.45	0.0204	0.0015	0.0000	0.0675	1.65	11.4	1.3	5.71	5.12	1.10	0.088
"	September	0.32	0.0131	0.0019	0.0000	0.0408	2.63	13.9	——	5.47	4.91	1.84	0.041
1897	October	0.24	0.0133	0.0017	0.0000	0.0703	3.26	17.0	——	5.13	4.86	2.36	0.048
"	November	0.20	0.0147	0.0021	0.0000	0.0600	3.58	20.4	2.2	4.42	4.02	2.16	0.119
"	December	0.29	0.0080	0.0014	0.0000	0.0806	1.84	11.9	0.4	2.31	1.89	1.26	0.102
1898	January	0.22	0.0061	0.0014	0.0000	0.1060	1.47	12.0	1.7	2.06	1.67	1.51	0.126
"	February	0.24	0.0101	0.0017	0.0000	0.1500	1.38	11.1	0.3	2.94	1.91	1.14	0.088
"	March	0.22	0.0085	0.0014	0.0000	0.0450	1.24	10.4	0.4	2.81	1.87	1.00	0.038
1898	April	0.20	0.0084	0.0026	0.0000	0.0431	1.45	9.1	0.1	2.69	2.07	1.25	0.045
"	May	0.27	0.0088	0.0012	0.0000	0.0255	1.30	9.3	1.2	2.58	2.18	0.79	0.040
"	June	0.23	0.0083	0.0020	0.0000	0.0300	2.12	12.2	2.3	3.27	2.96	0.95	0.014
1898	July	0.24	0.0095	0.0026	0.0000	0.0637	2.67	14.6	2.2	4.01	3.30	1.55	0.021
"	August	0.29	0.0104	0.0024	0.0000	0.0495	2.45	16.7	5.4	3.07	3.08	1.02	0.015
Average, excluding July, '97		0.27	0.0105	0.0018	0.0000	0.0641	2.08	13.1	1.6	3.69	3.07	1.38	0.060

TABLE No. 12 D.

Average Results by Months of Chemical Analyses of Samples Collected from Sand Filter No. 1.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897	July	——	0.0184	0.0051	0.0001	0.1243	2.02	28.9	1.2	6.59	9.12	1.26	0.127
"	August	0.35	0.0100	0.0009	0.0001	0.0707	1.51	10.3	——	7.30	7.16	1.07	0.034
"	September	0.06	0.0076	0.0014	0.0000	0.0548	2.43	13.8	——	6.52	6.07	1.91	0.006
1897	October	0.00	0.0078	0.0017	0.0000	0.0816	3.12	17.4	——	5.99	5.60	2.52	0.006
"	November	0.10	0.0097	0.0014	0.0000	0.0771	3.62	18.5	0.0	5.01	4.74	2.23	0.024
"	December	0.02	0.0056	0.0015	0.0000	0.0937	1.90	11.7	0.0	3.26	2.81	1.36	0.031
1898	January	0.12	0.0049	0.0011	0.0000	0.1020	1.39	9.9	0.0	3.13	2.63	1.52	0.028
"	February	0.10	0.0077	0.0013	0.0000	0.1625	1.44	10.9	0.0	3.23	2.68	1.22	0.028
"	March	0.00	0.0040	0.0016	0.0000	0.0525	1.23	9.5	0.0	3.59	2.74	1.05	0.016
1898	April	0.02	0.0050	0.0021	0.0000	0.0469	1.56	8.7	0.0	3.46	2.88	1.14	0.010
"	May	0.09	0.0048	0.0010	0.0000	0.0270	1.31	8.3	0.0	4.12	3.30	0.86	0.012
"	June	0.06	0.0057	0.0016	0.0000	0.0412	2.14	11.2	0.0	4.42	4.10	1.01	0.004
1898	July	0.09	0.0055	0.0023	0.0000	0.0731	2.60	14.2	0.0	5.97	4.67	1.66	0.005
"	August	0.12	0.0050	0.0022	0.0000	0.0465	2.56	12.5	0.0	5.36	4.37	1.12	0.004
Average, excluding July, '97		0.09	0.0064	0.0015	0.0000	0.0715	2.06	1.21	0 0	4.72	4.13	1.44	0.016

TABLE No. 12 E.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SAND FILTER No. 2.

(Parts per 100,000)

Year.	Month.	Color.	Nitrogen as Albuminoid Ammonia.	Nitrogen as Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron
1897	July	——	0.0158	0.0059	0.0001	0.1158	1.90	23.9	4.4	7.25	22.15	1.99	0.130
"	August	0.35	0.0101	0.0009	0.0000	0.0760	1.58	10.5	——	7.35	7.20	1.17	0.036
"	September	0.06	0.0078	0.0015	0.0000	0.0533	2.40	13.8	——	6.63	6.07	2.01	0.004
1897	October	0.00	0.0082	0.0015	0.0000	0.0722	3.17	17.9	——	6.12	5.74	2.55	0.005
"	November	0.09	0.0091	0.0015	0.0000	0.0761	3.35	18.4	0.0	5.68	5.33	2.27	0.023
"	December	0.04	0.0064	0.0012	0.0000	0.0731	1.89	11.5	0.0	3.21	2.76	1.29	0.029
1898	January	0.11	0.0046	0.0012	0.0000	0.1050	1.42	10.7	0.0	3.47	2.84	1.48	0.025
"	February	0.08	0.0073	0.0014	0.0000	0.1000	1.41	11.0	0.0	3.50	2.77	1.22	0.041
"	March	0.02	0.0039	0.0017	0.0000	0.0550	1.24	9.4	0.0	3.81	3.07	1.04	0.026
1898	April	0.02	0.0046	0.0021	0.0000	0.0469	1.42	8.6	0.0	3.62	3.02	1.14	0.012
"	May	0.10	0.0046	0.0011	0.0000	0.0255	1.25	8.2	0.0	3.81	3.32	0.74	0.011
"	June	0.05	0.0060	0.0014	0.0000	0.0319	2.16	11.4	0.0	4.58	4.30	1.04	0.003
1898	July	0.06	0.0057	0.0024	0.0000	0.0769	2.37	13.5	0.0	5.77	4.39	1.54	0.004
"	August	0.15	0.0049	0.0025	0.0000	0.0480	2.56	12.1	0.0	5.24	4.04	1.30	0.004
Average, excluding July, '97		0.09	0.0064	0.0016	0.0000	0.0646	2.02	12.1	0.0	4.83	4.22	1.45	0.017

TABLE No. 12 F.

Average Results by Months of Chemical Analyses of Samples Collected from Mechanical Filters.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as: Albuminoid Ammonia.	Nitrogen as: Free Ammonia.	Nitrogen as: Nitrites.	Nitrogen as: Nitrates.	Chlorine.	Residue on Evaporation: Total.	Residue on Evaporation: Suspended.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
						Warren Filter.							
1898	February	0.04	0.0055	0.0020	0.0000	0.0875	1.34	7.7	0.0	2.04	1.23	1.53	0.009
"	March	0.00	0.0039	0.0015	0.0000	0.0487	1.29	7.8	0.0	1.94	1.15	2.00	0.007
"	April	0.01	0.0041	0.0016	0.0000	0.0467	1.19	7.9	0.0	1.86	1.31	1.47	0.005
1898	May	0.05	0.0052	0.0014	0.0000	0.0285	1.38	8.2	0.0	2.66	1.48	1.44	0.014
"	June	0.06	0.0049	0.0015	0.0000	0.0319	2.11	10.2	0.0	4.06	2.10	1.93	0.003
1898	July	0.00	0.0045	0.0018	0.0000	0.0700	2.32	11.5	0.0	3.83	2.42	2.02	0.002
"	August	0.05	0.0051	0.0032	0.0000	0.0450	2.34	11.7	0.6	4.02	1.65	2.19	0.002
Average		0.03	0.0047	0.0019	0.0000	0.0512	1.71	9.3	0.1	2.92	1.62	1.80	0.006
						Jewell Filter.							
1898	February	0.08	0.0038	0.0017	0.0000	0.0862	1.31	7.8	0.0	2.27	1.41	1.38	0.010
"	March	0.00	0.0035	0.0015	0.0000	0.0534	1.17	7.3	0.0	2.09	1.21	1.59	0.006
"	April	0.00	0.0042	0.0018	0.0000	0.0475	1.22	7.8	0.0	1.93	1.44	1.21	0.008
1898	May	0.01	0.0040	0.0013	0.0000	0.0214	1.36	8.1	0.0	2.62	1.49	1.42	0.004
"	June	0.05	0.0050	0.0021	0.0000	0.0319	2.03	10.4	0.0	3.83	1.91	2.11	0.003
1898	July	0.05	0.0047	0.0017	0.0000	0.0600	2.40	13.6	0.0	4.57	2.48	2.23	0.003
"	August	0.04	0.0058	0.0027	0.0000	0.0435	2.45	11.6	0.5	3.87	2.10	1.72	0.002
Average		0.03	0.0044	0.0018	0.0000	0.0491	1.71	9.5	0.1	3.03	1.72	1.67	0.005

ARBITRATION.—ITS PLACE IN OUR PROFESSIONAL PRACTICE.

By G. Alexander Wright, Member, Technical Society of the Pacific Coast.

[Read before the Technical Society of the Pacific Coast, Nov. 2, 1900.*]

I do not expect to be able to present for your consideration this evening anything that can be justly termed new or original. My paper consists largely of notes made from time to time for my own guidance, with an occasional suggestion based upon experience with technical arbitrations. I will say frankly that I believe the arbitration of disputes connected with their professional work is, and should be, closely allied to the legitimate modern practice of the architect and of the engineer.

If my attempt to throw some light upon this important subject results in an interchange of thought between us, the object of my paper will have been accomplished.

The word arbitration comes to us from the Latin "Arbitratus" (to be a hearer) and "Ar" and "betere" (to go hence; one who goes to look on). This method of determining differences between men has been practiced from earliest times, and distinct references to its principles are found in the Scriptures. The Amphictyonic Council, organized 600 B. C. for the protection of the temple of the Delphi and for the abolition of war, also proposed the accomplishment of its object by arbitration very much as we know it to-day. So well recognized were these principles in Greece that when Sparta and Argos made a treaty of alliance they provided for settlement of their disputes by arbitration (as we are told) according to the custom of their "ancestors." Rome, in the pride of her glory and power, acknowledged the good side of arbitration when Pompey directed the Parthians and Armenians to regulate their differences by this means. It is interesting for us to observe also that the arbitration proceedings of to-day differ but very little from those of the ancient Greeks. In their day it was usual to make agreements, designating the arbitrator, and also the matters in dispute. It was the arbitrator who fixed the time and place of the investigation, and he was solemnly pledged to honestly discharge his trust. The "sentence" was also written out and deposited in temples or other public places, and oaths were taken by the parties that they would execute the sentence imposed.

*Manuscript received November 12, 1900.—Secretary, Ass'n of Eng. Socs

During the Middle Ages arbitrations seem to have been more frequent, yet their beneficial influence was restrained owing to the absence among the people of the idea of conciliation. Happily, in modern times arbitration is more universally appreciated as a means of settling differences of every kind, from those of international importance to the adjustment of those manifold questions which continually affect capital and labor. So general, indeed, is this principle that in some States even breaches of contract, trespass, assaults, charges of slander, differences of partners and even breach of promise may be settled by arbitration; and so the principle has come down to us in an almost unbroken line from ancient times.

Referring for a moment to international arbitration, it is but a short time since the Emperor of Russia advocated a national conference with the object of substituting its principles among nations as a remedy for war. It should be a matter of considerable pride to us as American citizens to recall the fact that, since her birth as a nation, the United States has ever been foremost in consenting to the arbitration of questions which other nations might have considered a justification for bloodshed, and we find no fewer than forty-seven such cases in a little over one hundred years,—an excellent showing indeed. And, in addition to arbitrating her own differences, the United States has herself acted as arbitrator between other nations on some fourteen different occasions.

But, to return, there are probably no professions in which the spread of this principle has, during recent years, been greater than in connection with our contract methods of carrying out work, and we as architects or engineers may at any time be called upon to apply the recognized principles of the practice of arbitration. Our professional literature, however, seems to be somewhat silent on this useful subject. There are legal works for the attorney, of course, containing the law in the premises, the code and digests of many cases that have been heard arising out of "arbitration" proceedings, the most frequent examples being the efforts of parties wishing to set aside awards; but there is very little published adapted to the needs of the layman who finds himself, for the first time, occupying the position of arbitrator.

Let us therefore briefly consider the subject to-night as practical laymen rather than from the legal standpoint.

In the trial of technical suits there has never been a time when the best technical testimony has been more sought after than now, and the reason for this is not far to seek. Indeed, the time is not far distant, I think, when the courts will realize the advantage of referring such technical cases entirely to the professional expert.

This method is quite prevalent in older countries, and it is of immense advantage to litigants, while at the same time it greatly facilitates the work of the courts. Who is there among us who does not recall some technical case which ought to have been determined by arbitration rather than by a suit? Is it not safe to say it would have been settled more quickly, more economically and perhaps more satisfactorily to the parties concerned?

Arbitration, as regulated by statute, certainly results in prompt and equitable settlements, and without causing that bitterness of feeling between the parties which sometimes results in enforcing their claims in our courts of law. It is a practical remedy for long-continued technical suits, and can be applied by practical men who certainly have the advantage of understanding the technical points involved. In short, it may be called the substitution of reason for force.

Take an ordinary case, one that might arise any day in our practice. A client, for example, declines to pay for extra work; by no means an uncommon incident. In such a case arbitration may arise by the terms of the contract or by subsequent consent of the parties. Either of these methods is better for the disputants than a suit, because no expense or loss of time is incurred in preparing and waiting for trial. This is no small advantage in itself.

The first step is for the disputing parties to enter into an agreement whereby they consent not only to arbitrate their differences, but to abide by the award. This agreement is technically known as the submission, and the subsequent award depends largely upon its terms and conditions. Its preparation requires some care, and this is often attended to by the attorney of one of the parties and submitted for the approval of the attorney on the other side. But there is no reason why it cannot be prepared by an engineer or an architect, the same as he may prepare his award, or a contract, or specification or any other document required in his regular practice, provided the submission be in accordance with Section 1283, Code of Civil Procedure. Assuming, however, that the submission is best prepared by the attorney of one side, I have found it no disadvantage for the arbitrators to be acquainted with the fundamental principles involved, and it is these only with which we are now dealing. But the essential point involved in this question of arbitration is not so much in the technical knowledge necessary to prepare a submission as it is to so present the facts to disputing clients and others that they shall prefer arbitration in place of resisting technical claims in the courts. Indeed, I do not think professional ethics would be violated if at every suitable opportunity

we were to give prominence to the advantages of arbitration over actions at law in matters of technical dispute.

The submission must be in writing, and, if proceeding under the provisions of the Code of Civil Procedure, it may be entered as an order of the Superior Court. This is done by filing the document with the clerk of the county in which one of the parties resides. In San Francisco the filing fee is $6.00. A note of the filing of the submission must thereupon be entered by the county clerk in the Register of Actions, as held in the case of Kettleman *vs.* Treadway, 65 Cal. 505. The mere authority to file, without the act, is insufficient, but by inspecting the Register of Actions an arbitrator may always satisfy himself that this has been done. The entry should contain the necessary particulars,—for example, the names of the arbitrators and the time limited by the submission (if any) within which the award must be made. After such entry has been made a submission cannot be revoked without the consent of both parties. But in the case of the California Academy of Sciences *vs.* Fletcher, 99 Cal. 207, it would appear that the word "thereupon" does not necessarily mean "immediately," for in this case such entry was not completely made until nineteen days after the award was made and filed; but it was held that jurisdiction did exist to enter judgment upon the award, which was done. We see, therefore, that the submission may be filed at any time before judgment is entered upon the award.

In a general way any person legally capable of making a contract may submit controversies to arbitration, but it must be remembered that a single partner cannot bind his co-partners to arbitration unless his co-partners have wholly abandoned the business to him, or are incapable of acting (Sec. 2430, C. C. P.). The case of Jones *vs.* Bailey, 5 Cal. 345, has a good decision on this point.

Arbitrators should allow a reasonable time when fixing a date of hearing, in order that both sides may be ready to present their respective claims and testimony.

Should either side wish to be represented by counsel before the Board of Arbitration, it would be proper to notify the other side of such intention; and, although arbitrators are not bound to hear counsel, it would scarcely seem to be right to refuse to do so. In such cases especially the attendance of a stenographer is desirable to take verbatim notes of the proceedings.

Although not compulsory, I have found it a good plan to have a schedule of the specific matters in difference made part of the submission. This prevents the possible importation of other matters by the parties during the hearing, a practice which, if permitted, always causes unnecessary discussion and loss of time.

A disputant may nominate any person as his arbitrator, for every person has the right to select whom he pleases for his private judge; but in seeking to take the benefit of his right to arbitration he should use discretion and judgment, such as might be displayed, for example, in the selection of a juryman.

In matters of accounts mercantile men are often selected; in other cases attorneys; in others architects or engineers, and so forth, according to the nature of the subject-matter in dispute. An arbitrator's chief qualifications are good judgment, impartiality, clear-headedness and patience. He should be absolutely free from bias or feeling in act and expression. If he is unfriendly in the slightest degree toward the party on the opposite side, it would be better for him not to act. Should the parties happen to be either his creditors or debtors, that alone need not prevent his acting. He should not accept any favors, nor even any part of his legitimate fees prior to the award. Such acts are liable to misconstruction, although done in the best of good faith. Disputants should beware of nominating as arbitrator persons known to be prejudiced in their favor, or whose minds are already made up regarding any of the matters in difference. No honest arbitrator would act under such conditions. Indeed, in such a case the subsequent proceedings would become a farce instead of a benefit.

Above all, his mind should at all times be open to honest conviction, any disposition to stubbornness or laxity being carefully avoided. In short, much depends upon the judgment and broad-mindedness of an arbitrator.

Having been appointed and named in the submission signed by both parties, the arbitrator's first duty is to qualify before an officer authorized to administer oaths, by declaring that he will faithfully and fairly hear the allegations and evidence and make a just and true award according to his understanding; and the umpire, when appointed by the arbitrators, will also make similar oath.

Regarding the "powers" of arbitrators, they occupy a similar position to those of judges of the Superior Court, the principal exception being that they are without contempt powers. They should endeavor as far as possible to arrive at correct conclusions by the same rules as would have governed the court for which they have, for the time being, been substituted. The exact terms of the submission must be closely followed, and its specific language complied with. Arbitrators, however, are neither expected nor compelled to follow court methods exactly. Indeed, if the award is an equitable decision, made in good faith, the actual law in the

case may be disregarded, and the award would not necessarily be thereby rendered invalid and void; but, if it can be shown that the arbitrators intended to decide according to law and that they were in error, then the court might set aside the award.

It is the arbitrators' duty to appoint a time and place of hearing; to notify the parties thereof; to adjourn as often as necessary; to administer the oath, and, above all, they must act "together," and *not* individually, in all things. The majority may determine any question. In other words, two may do any legal act authorized by the terms of the submission that three may do. They must decide on *all* the controversies submitted, omitting to consider nothing and leaving nothing in doubt or undecided. They must, of course, hear evidence on both sides. Lord Eldon, the eminent jurist, once said, "By the great principles of eternal justice (which is before all acts, regulations and proceedings of court), it is impossible that an award can stand where arbitrators hear one side and decline to hear the other." I think the case of Curtiss *vs.* City of Sacramento, 62 Cal. 102, presents an interesting point. It is an application to set aside an award on the ground that no opportunity was given the parties to submit evidence, and, briefly, the point arose in this way: Two arbitrators met, without a third, and took testimony; the third one arrived at a decision by reading over the notes of the evidence without being present when it was given. It was held that the award was invalid and void.

The duties of the arbitrator must not be delegated to another. If, however, the opinion or knowledge of any person (for example, an independent attorney) is necessary to "confirm" the understanding of an arbitrator, it is allowable to obtain such assistance, but the greatest possible care must be taken not to blindly follow such person's opinion or knowledge. Again, in the same way, it is customary for an arbitrator, when necessary, to consult with outside parties regarding, for example, matters of construction or prices, but it must be for the purpose only of fortifying his own opinion. This also should be done with caution, for, as a matter of principle, it is dangerous to go outside for evidence, and perhaps it is safer, after all, to obtain opinions by placing such parties upon the witness stand in the regular way.

Each arbitrator should carefully study every detail of his case, however small, bearing in mind "precedents," trade customs, etc., if any exist, and leaving nothing to chance. Still, arbitrators must remember that they are judges, not advocates, of the parties. I have met inexperienced arbitrators whose sole idea of their duty seemed to be to advocate for and to take everything in sight,

regardless of equity and justice. But this is not arbitration. It is a direct violation of the arbitrator's oath to hear fairly the allegations and to make a just and true award according to his understanding.

In some "submissions" I have seen a clause to the effect that the parties agree not to appeal from the award, but this does not of course prevent the court from exercising its jurisdiction if occasion demands.

My knowledge of the statutes is insufficient to warrant my saying that the Legislature intended an arbitrator's award to be absolutely final and beyond appeal (except, of course, for fraud), but I think such was the original intention, and I would certainly be in favor of an amendment making it so.

Now let us consider the matter of the third party, or umpire. Provision is made in the arbitration clause of many contracts that if the two arbitrators cannot agree they shall then select a third to act with them. It has been held in Dudley *vs.* Thomas, 23 Cal. 365, that arbitrators duly qualified may appoint the umpire at *any time,* and it would therefore appear that it is quite unnecessary to defer the appointment of umpire until disagreement between the two arbitrators occurs, although this may be so stipulated in a contract agreement. At any rate, it is found to be a bad and inconvenient condition in actual arbitration practice, and it is better and proper, in my opinion, for the umpire to be selected immediately after the arbitrators and before the investigation is commenced. A convenient arrangement is for him to act as chairman of the commission. By so doing he has the opportunity not only of hearing, but of directing the presentation of testimony from the commencement of the proceedings; and he is thus enabled to render his decisions without putting witnesses on the stand twice over, which would otherwise be necessary if the two original arbitrators were unable to agree.

The umpire should refrain from voluntarily joining in any discussion between the arbitrators in their efforts to agree, his duty being to decide if they cannot agree. Arbitrators should not permit parties to a submission to influence them in the nomination of persons to act as umpire. The selection lies with the arbitrators alone, and it makes no difference whether the parties are satisfied with such selection.

It may be also well to remember that an umpire must be "selected," and his appointment should be in writing by agreement between the arbitrators. But he should not be chosen by drawing lots or by the tossing up of a coin, a method which I have known to

be suggested when the names of two or more equally eligible parties have been named for umpire. A case sometimes occurs in which arbitrators, although acting in perfectly good faith, are unable to agree upon a third party, and I am unaware of any power of the courts to compel arbitrators to agree on an umpire. Not so long ago I had a case of this kind in my own practice. The conditions were such that it was impossible to agree upon an umpire. My co-arbitrator was inexperienced and stubborn. The arbitration was abandoned. Suit followed, and in due course judgment was rendered in favor of my co-arbitrator's side, but for about one-third of the amount which, I feel sure, would have been awarded by arbitration. This is a good illustration of the effect of stubbornness on the part of an arbitrator.

Touching upon the subject of evidence, all witnesses must of course be sworn. Plans, specifications, correspondence, etc., should always be identified by testimony and numbered as exhibits before being admitted as evidence. Memoranda made in books by one of the disputants stand in very much the same light as heresay evidence, and should be accepted with reserve, for nothing can prevent any one from making entries exactly to suit his case. Such entries may be used, however, by the opposite party if so desired.

A jury is very apt to attach undue importance to a large number of witnesses, but a few good men of known reputation are more convincing to technical arbitrators, for they have the necessary skill and judgment to be able to decide for themselves just what portion of such evidence they may justly accept or reject. This, I think, is a strong argument; not only in favor of arbitration itself, but in favor of technical arbitration occupying its proper place as a branch of our professional work.

A few words about the award. When all the testimony is in and the controversies are decided, the arbitrators prepare their award, usually in writing, although a verbal award, in other respects good, would not be invalid.

It is usual to recite from the submission the authority for the investigation, and other points essential to clearness. The award should preferably be written by the arbitrators, or one of them, and not, for example, by the attorney of one of the parties. It must be definite, unmistakable and conclusive in its language. The expression sometimes used by arbitrators, "We *propose* that such a thing should be done," is ambiguous, and should not be employed. "We *direct*" is much to be preferred.

The award must not only state the amount of money due from one party to the other, but it should direct its payment and when it

is to be paid, otherwise non-payment would not constitute a disobedience of the award. It should conform to the terms of the submission, and deal only with the specific matters of controversy, and nothing more nor less. It should state, moreover, that all the evidence has been heard, and that all disputed matters have been determined and closed; otherwise the award is liable to be held defective and to be set aside. The greatest care is necessary in writing out the award, for it cannot be legally altered by the arbitrators even to correct errors. Any corrections so made will be void, and the language originally written will stand good. The court may, however, on motion, correct or modify an award upon a proper showing, as, for example, in the case of a miscalculation of figures.

Arbitrators are not required to give details of their figures, nor reasons, nor explanations for arriving at their conclusions any more than judges of the court are required to do such things. Comments or discussions thereon with the parties or their acquaintances are best avoided.

If the submission has been filed with the county clerk, the award must also be filed and a note thereof made in the Register of Actions, in order that the award may be entered as a judgment or order of the court.

An award may be set aside if serious irregularities can be shown,—for example, corruption, fraud, gross error or material irregularity; refusing to postpone a hearing, or acting in such a way that the rights of the parties were prejudiced. But an award cannot be impeached solely as being contrary to law and evidence (see Carsley *vs.* Lindsay, 14 Cal. 394). This is a good point to bear in mind. I remember a recent case in which one of three arbitrators declined to sign the award, upon the ground that it was contrary to the evidence, and he filed a minority report to this effect. But it will be seen that this proceeding would have been of little or no value in any attempt to impeach the award. As a general thing I think it is better *not* to make a "minority" report, notwithstanding an arbitrator may not be able to conscientiously agree to the award. Where it is possible to do so, it is better for all the arbitrators to unite and sign the award. I believe that even an attempt to set aside an award on the ground of refusing to hear certain evidence has been overruled, but I am unable for the moment to cite the case.

The reason for the foregoing seeming strictness exhibited by the courts in reference to arbitrations is because arbitration is a purely statutory proceeding, and there can be no doubt whatever that the statute must be closely followed.

Having touched upon the fundamental principles regulating arbitration, let us proceed to consider its advantages, especially in regard to those technical disputes which come under our observation as engineers and architects.

A court trial differs of course from one held before technical judges. In the former witnesses are always entitled to be considered as truthful until proved to be otherwise. The court knows nothing personally of the "weight" which might reasonably be attached to their technical testimony beyond what appears on the face of the evidence; whereas technical or trade witnesses testifying before a technical tribunal would, in all probability, be personally known by one or more of them, and their reputations could be considered; and, such arbitrators being personally familiar with the subject-matter of such testimony, could make allowances, and estimate such evidence at its proper value.

Again, expert and also trade testimony in court have been known to differ considerably, but technical arbitrators would, of their own experience, understand such matters and be able to discover reasons for such differences or errors and, as I have stated, to make due allowances therefor.

Another advantage is that the hour and place of hearing may in some measure be fixed to suit the convenience of the parties and their witnesses. This concession cannot of course be obtained, nor expected, from the courts.

Sometimes it happens that neither the court nor disputants' attorneys are sufficiently acquainted with the true interpretation of drawings, details, specifications, etc., nor, indeed, with much of the technique appertaining to our professional work, nor can it be expected that they should be. And so it happens that we sometimes hear of the details of technical cases being insufficiently understood by both court and counsel during a trial. And although a verdict under such conditions may be a just one, as far as the *law* is concerned, it may not be "equity," viewed in the customary technical light of practical minds.

Then, as regards quick settlement of technical cases and costs, I submit that the best results are usually obtained by early arbitration, when all the matters are still fresh in the minds of all parties and of their witnesses. Indeed, this very point has recently been brought forcibly to my attention, for during the time in which I was engaged in preparing this paper I was subpœnaed to give testimony in a suit regarding the quantity of certain work done in a building not far from here, and I found that the dispute had extended over three years, although the amount of the claim was

only about four hundred dollars. But if the matter had been arbitrated three years ago a saving of time and money would have been effected, and probably without producing strained relations on either side.

Then, again, in arbitration there is more opportunity and latitude for producing rebuttal evidence, but in court, if the best and strongest testimony be not produced according to the rules of the court, the opportunity of doing so may be lost. Again, there is less risk of one side being overthrown by "surprise" testimony, as occurs sometimes in court. Technical arbitrators have a way of getting down into the facts. They go at once to the very essence of the dispute, and are hampered neither by court rules nor by precedent. In short, they get at the facts, and are able to render judgment accordingly in a common-sense, practical manner.

It is only right perhaps that I should refer to one or two of the objections which one occasionally hears against arbitration. I have heard it alleged that arbitrators may be uncertain judges, admitting evidence of a certain nature at one time and rejecting it at another. It is sometimes said that arbitrators are liable to be inconsistent regarding the weight of evidence submitted, or that they may be very firm and hard to convince to-day and unnecessarily yielding to-morrow, and so on. But these objections do not hold good, I think, where arbitrators have had the advantage of experience. I have heard it stated that arbitration is good provided there are perfect arbitrators, but would it not be equally reasonable and convincing to say that the courts are good provided every judge is perfect? And it is doubtful whether his honor himself could maintain that this condition has always existed, though it is very far from my intention to suggest the least disrespect to the honorable and painstaking judges of our courts.

It of course happens sometimes that both parties to an arbitration are no more satisfied with an award than others may be with a court decision. This often arises from a misunderstanding or lack of knowledge as to the real objects of arbitration. Occasionally one meets those who cherish a grievance unless they are awarded the whole, or nearly so, of whatever they choose to claim. But such cases are very rare, and they in no way affect the great principle,—viz. the undoubted advantage of the application of arbitration to technical disputes. As a general rule I find fair-minded and reasonable persons are not only satisfied with awards, but heartily glad to get their differences so quickly adjusted and off their minds without resorting to an action at law. While it is true that some contract agreements provide for arbitration of disputes

between the actual parties to such contract, this provision does not of course provide for settlement of any disputes that may arise between other parties, and which do arise; and we have but to refer to the court calendar to see how frequently such technical cases are taken into court.

Having now touched briefly upon the fundamental principles of arbitration, I may be excused perhaps for presenting for your consideration one or two thoughts that have occurred to me in regard to the settlement of those differences which affect the engineer and architect, the contractor and the client.

First. Arbitration is perhaps one of the most practical of subjects in the statutes. A practical man can understand and readily apply its fundamental principles; a further knowledge of which might well form a part of our professional training, enabling us to occupy with better advantage the position of technical arbitrator when the necessities of our practice require it.

Second. I would even favor compulsory arbitration of all technical or trade disputes, believing that the interests of all can best be served by its adoption. Take, for example, the differences which will sometimes arise between the professional man and his client. Most of us know something of the uncertainty of submitting such differences in court to a jury of laymen. Such matters should, I think, be invariably adjusted by technical men who are familiar with what is right and proper in such cases.

Third. It would seem to me to be an important advantage to technical disputants and a relief to the court calendar and practice if a permanent technical court or tribunal could be established, where all cases, such as occur in the work of the engineer and architect, might be referred and be quickly determined beyond appeal by technical men along arbitration lines; or, if this should be considered too sweeping a change in our judiciary methods, then perhaps a particular judge might be set apart and be given a special court to try (in conjunction with technical advisers who would sit in bank with him) the particular classes of cases under consideration. These, gentlemen, are merely suggestions which I offer as being possible remedies for existing conditions, and which are known to be capable of improvement by those of us who have had experience with technical trials in courts of law.

In conclusion, I hope I have not detained you too long. If my enthusiasm has led me into saying too much, it is because I believe in my subject, believe in its equity and believe it to be the quickest and most inexpensive process for settling those vexatious technical disputes which sometimes arise. These are also my reasons for believing that arbitration has its place in our modern professional practice.

A SUCCESSFUL SIPHON.

By Robert S. Hale, Member Boston Society of Civil Engineers.

[Read before the Society, October 17, 1900.*]

The following paper describes the solution of a problem occurring in a small water-supply plant. The problem has been solved satisfactorily by the use of an air-tight siphon at a cost of about $250, as against a cost of several thousand dollars which would have been incurred if the pipe had been laid to grade, or as against less efficient service together with an annual cost of nearly $100 if an air chamber had been provided and kept free of air by a pump. While the solution is simple, it was not referred to in the text-books or reference books which I consulted, nor was it thought practicable by a number of engineers with whom I talked the matter over. A description may therefore prove of interest.

The Bee Hive Mountain Aqueduct Company is a private company supplying seven houses and four barns at Schooner Head, Bar Harbor, Maine. The works supply also a private golf course and a number of lawns, requiring a good deal of water for sprinkling. The supply is taken from a small pond at about 400 feet above sea level. Close to the pond is a ridge about 200 feet wide, rising to 12 feet above the level of the pond, through or over which the water must be carried to the houses. These are from 20 to 100 feet above sea level, or an average of about 350 feet below the level of the pond.

The houses are inhabited only during warm weather, and this fact obviated any necessity of burying the pipes. The first installation consisted of a 2-inch galvanized iron pipe, with screw joints, laid over the ridge. This siphoned the water over the ridge and would work satisfactorily for a few hours, after which time the siphon would break. Two or three of the plumbers at Bar Harbor, including the one who laid the first pipe, took turns in taking contracts to keep the siphon in operation for the season, but the only successful method was to open a waste pipe about 200 feet below the level of the ridge. This waste pipe gave a continuous flow through the siphon, and the result was satisfactory so far as the supply of water at Schooner Head was concerned. The method, however, involved an excessive waste of water, which lowered the level of the pond to an undesirable amount and reduced the available pressure at the houses.

*Manuscript received November 24, 1900. — Secretary, Ass'n of Eng. Socs.

Among the other means which were tried to keep the siphon in operation were:

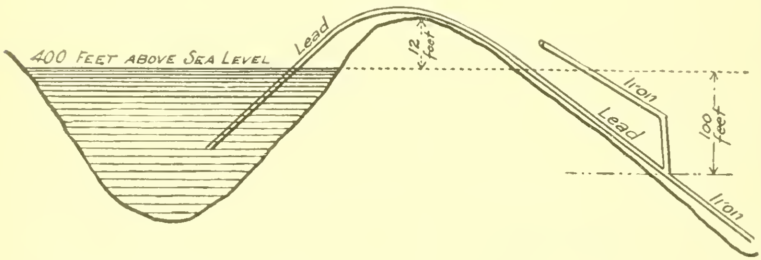
1. The use of foot valves at the pond.

2. The use of a vent on the delivery side, in order to prevent air backing up to the top of the siphon.

3. Taping the joints of the pipe with electric tape. This kept the siphon in operation eleven days, when the supply failed. The joints were retaped and the siphon restarted, after which it held three days and then failed again. After that, taping the joints seemed to have no effect.

4. Tarring the joints. This could not be well done, as the pipe could not easily be heated before applying the tar.

After the plumbing contractors of Bar Harbor had tried for several years to keep the siphon in operation without the waste of water due to the drip, the matter was referred to a committee



consisting of Mr. G. T. Francis, Mr. R. W. Hale and myself. Mr. W. L. Pierce, a contractor of Bar Harbor, was anxious to try a lead pipe for the siphon, while some of the directors of the company desired to cut through the ridge. On obtaining estimates of cost, it appeared that it would cost about $6000 to cut through the ridge (which was all rock), and about $250 to lay a 1-inch lead pipe. It also appeared, from the study of the means previously tried for keeping the siphon in operation, that the failures were due to indraft of air through the joints of the iron pipe, which would not occur if lead pipe with wiped joints were used. That the trouble was due to air leaks at the joints was indicated also by the fact that the joints all leaked when put under water pressure.

The committee, therefore, reported in favor of a lead pipe, and this was put in last spring, water being turned into it on April 9. The siphon has held continuously from that day to October 17, the date of writing, without breaking and without waste. The result is a complete success, and the level of the

pond is hardly appreciably lowered by the use of the water, instead of being lowered several feet as in former years (on account of the waste pipe). The pressure at the houses is higher than ever before, since the loss of head due to replacing 500 feet of 2-inch iron pipe with 1-inch lead pipe is less than was the loss of head due to the waste pipe formerly kept open.

The present arrangement of the pipes is as shown in the sketch.

A portion of the old 2-inch iron pipe, some 200 feet long, serves as a vent to get rid of any air carried over from the pond. See figure.

A rough estimate of the delivery of the siphon was made by placing the end of the lead pipe horizontal (by spirit level) and measuring the fall of the jet below this level in a given distance.

The computations showed a friction coefficient of 0.032 where Merriman's tables give 0.029. This agreement is closer than can be expected for such rough measurements, and it is safe to say that the pipe delivers nearly the same quantity that it would if there were no siphon.

When the lead pipe was delivering from its lower end into the air it was noticed that every few seconds a bubble of air came over from the pond. This may have been due to an air leak at some point, or to air that was given off from the water at the top of the siphon at less than atmospheric pressure, and that had not had time to redissolve. The latter is the more probable cause, since a leak would cause the siphon to break, which it has not done since it was started under the new conditions.

When considering the general question of a siphon, a short study of authorities showed me only two references. Merriman (page 192) merely says that a pump must be placed at the highest point. Kent (M. E. Handbook, page 582) describes two siphons, neither of which worked unless air was removed. When running, one gave about 25 per cent. less than the theoretical, and the other gave the same as the theoretical discharge for that size of pipe. The 25 per cent. deficiency in the first case may have been due to an unnoticed accumulation of air at some point.

No reference was found to any siphon that worked without removing the air, or to any attempt to make a siphon air-tight.

It should be noted that the Bee Hive Mountain pipe is a very small one, and that the velocity is high enough to carry small bubbles of air over the ridge and down to the vent pipe. For a large size of pipe the velocity necessary to carry air bubbles over the ridge must be higher than for a small pipe, and for a very

large pipe an air chamber might be necessary even for an air-tight pipe.

CONCLUSIONS.

First. The past and present experience of the Bee Hive Mountain Aqueduct Company indicates that the former breaking of its siphon was due to indraft of air at the joints. It is probable that this is the case with most siphons that give trouble.

Second. The use of an air-tight pipe (such as a lead pipe with wiped joints) will, for small pipes at least, make a siphon deliver permanently without the use of air pumps or chambers.

Third. The use of a vent pipe on the delivery side, as at the Bee Hive Mountain Aqueduct Company, which frees the pipe from air instead of letting the air back up into the siphon, is probably an advantage.

Fourth. While lead pipe is expensive, yet there are probably a number of cases, besides the one described, in which the use of a siphon made of air-tight pipe will be cheaper than either laying the pipe below the hydraulic gradient, or using an air chamber and pump.

OBITUARY.

William Giddings Curtis.

THE Technical Society of the Pacific Coast has lost one of its prominent and active members in W. G. Curtis, late engineer of maintenance of way, Southern Pacific Company, who died at Highland Springs, California, June 15, 1900.

He became a member in the early history of the organization, and always evinced a lively interest in the affairs of the Society, having been elected for a number of terms to the Executive Council and to the Vice-Presidency, which brought him in direct contact with many of the active members, who always found in him a genial companion, an accomplished gentleman and an engineer of great experience in the particular line which he had, in every sense of the word, made his life's work, and in which he was always found ready and willing to give the benefit of his observations to his fellow engineers.

Mr. Curtis, with his manifold professional duties, always found time to do his share of the Society's work. When approached for a professional paper he usually acquiesced, and when he did so he made his subject a serious study and brought his well-digested data to the notice of our members in such shape that it became of immediate practical value.

An instance in this direction is a paper written six years ago on the subject of "Timber Preserving Methods," which found such a wide circulation that it will be necessary for the Society to have it reprinted in the immediate future.

As many as thirty copies were sent to South Africa, and only recently six were sent upon an application from an eminent consulting engineer in Cape Town.

It is with great regret that your committee performs the sad duty of embodying in a memoir a few of the salient features that now make up the history of this remarkable life, which was ended in its very prime, when, with every faculty sharpened and matured, so much more might have been accomplished which must now be our loss.

Our late member was born at Bridgeport, Connecticut, August 12, 1849. He came to California when a young lad of fifteen with his family, who settled here in 1864.

Mr. Curtis's ancestors were English. The first of the family to come to this country was William Curtis, who arrived in 1632

in the ship "Lion," from Essex county, England, and settled in Connecticut.

His engineering experience began early, and from the lowest round of the ladder, for he entered the railway service as a rodman in the engineering department in 1865.

A remarkable character like that of Mr. Curtis did not long remain unnoticed. His abilities were soon recognized, and he was promoted rapidly from position to position, until at his death he held that of engineer of maintenance of way, Pacific system and lines in Oregon, Southern Pacific Company.

The enterprises which Mr. Curtis undertook and carried to a successful completion were so varied, and many of them are so well known in connection with him by the engineers of this coast, that it would be needless to review or enumerate them.

Socially he was a general favorite. He was a man of many and varied accomplishments; of prodigious memory, affable in manner and refined in expression, so that he was respected and admired by all his associates and subordinates.

He was a fluent and graceful speaker, with finely modulated voice, elegant gestures and dignified address, who never failed to be entertaining whatever his subject might have been. As a writer he was clear and concise. He wrote numerous papers upon technical subjects, all of which are characterized by that painstaking study, close thought and logical reasoning which distinguished the man.

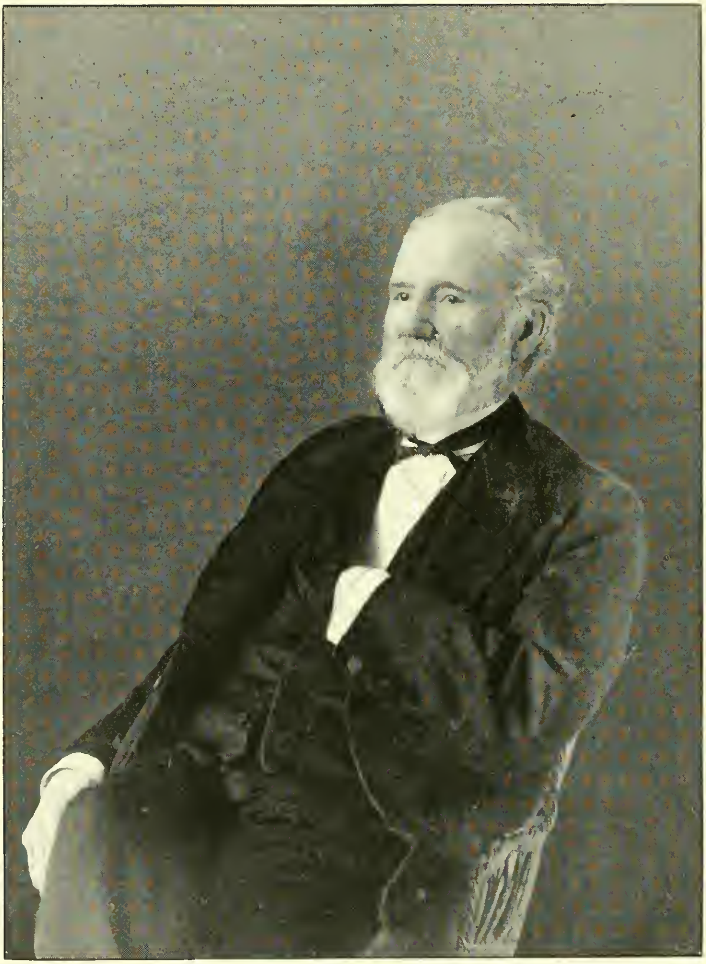
Mr. Curtis was married June 15, 1875, to Mary Elizabeth Burton, at Stockton, California, who survives him.

With these few points, taken from the life of this honorable, genial and accomplished colleague, your committee begs to offer the following resolution:

That in the death of William Giddings Curtis the Technical Society has sustained a very great loss, which all those must appreciate most keenly who have had the good fortune to come into close contact with this man.

As an engineer this loss is shared not only by the Southern Pacific Company, but by the entire technical profession, who will mourn his untimely death with us.

J. H. Wallace,
Otto von Geldern,
Committee.



JOHN H. BLAKE.

Honorary Member, Boston Society of Civil Engineers.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

STAMP MILLING OF FREE GOLD ORES.

BY DANA HARMON, MEMBER TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, September 7, 1900.*]

I WOULD not have it understood that I have reached any one given method of treatment applicable to all ores.

There are certain fundamentals to which I wish to address myself to-night. I believe that these underlying principles must be followed for all ores falling within the lines of my caption.

The local variance which must be had for ores of different localities are mainly those of screen and water, matters determinable by assaying the tailings.

MACHINERY.

Without going into the details of mill construction, it may be well to note some points bearing upon the work to be performed. Millwrights are seldom millmen.

Mortars and tables are of all shapes. Figs. 1, 2 and 3 show my own preferences.

There is such a wide difference in jar between the 850-pound and 1100-pound stamps that for the latter most substantial construction is essential.

BACK KNEE FRAME.

I prefer the back knee frame because of its solid bracing to the ore bin. The tappets are in plain sight; the pull of the belt is downward on the cam shaft; it requires less lumber. I build a flat-bottom ore bin in order to strengthen the anchorage and bracing.

The objections that such line shaft is subjected to dirt and awkward position need not lie. Set the base of the mortar 6 feet

*Manuscript received October 23, 1900.—Secretary, Ass'n of Eng. Socs.

above the ground, instead of $3\frac{1}{2}$ or 4 feet, as is customary with contractors. This will give plenty of head room around the shaft and pulleys. Tight wood boxes encasing the shaft bearings will keep out dirt. Plank or cement this mud sill floor. Whitewash every post and wall; oil cups on bearings.

In figuring on power, the uncertain factor is friction, and if bearings are to be saddled with dirt and gum, as in the dark they surely will be, power is wasted. The personal equation is an important item in connection with friction.

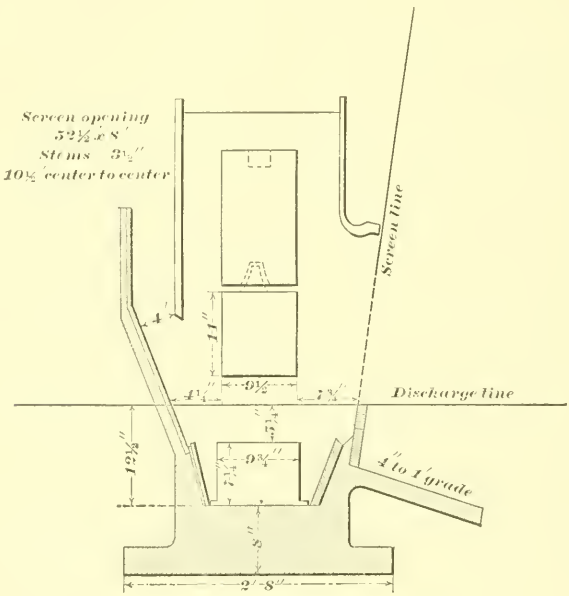


Figure 1.

Mortar, with steel shoe and iron die.

Mortar	7100	lbs.
Stem	440	"
Tappet	140	"
Boss	292	"
Shoe	244	"
Stamp	1116	"

MORTAR BLOCKS.

If wooden mortar blocks are used, make them long,—16 feet,—set on solid rock foundation, with a bedding of an inch of clean sand. Ram with concrete on sides and ends. This concrete should not be continuous all around the mortar blocks. There should be open spaces leading to the bottom of the pit; these spaces to be filled with sand, dry, or tailings run in. There is no better preservative to wooden mortar blocks than constant wetting. These sand pillars insure thorough saturation of the wood.

Excavate the pit so that you can also build up a concrete pier for the battery posts to rest on. Have anchor bolts in these piers, so that you can draw-bolt the battery posts and line sills solid to the concrete. Ordinarily the battery post is mortised into the line sill, the latter being bolted to the mud sills; but this method leaves a wide space and allows the post to spring.

The mortar blocks can be solid,—*i.e.*, two blocks bolted and keyed together,—or they can be built up of 2-inch plank nailed and bolted together. The mortar bolts are usually $1\frac{1}{2}$ x 30 inches. I think they should be longer, say 42 inches.

CONCRETE MORTAR BLOCKS.

Within the past few years concrete mortar blocks are coming into vogue. The concrete is capped with a single block of granite or iron, a sheet of lead between the mortar and this capping. Another plan has been to omit the granite or iron cap piece, and instead make the base of the mortar wider. Battery posts also are set on concrete piers.

I do not know how well these have withstood the jar of heavy mills, nor do I consider that their withstanding the jar of a 900-pound stamp is any evidence or proof of the effect an 1100-pound stamp will have upon them.

It is reasonable to expect greater crushing capacity from such rigid foundations. I should look for crystallized bolts because of this very rigidity. But I shall endeavor to show that in mortars set on wooden blocks we can crush as much as we are able to amalgamate.

It is urged against the wooden block that it will rot out in eight to twelve years; that it is well-nigh ruined if the mill stands idle a summer or two.

It has occurred to me—and I throw it out as a suggestion only—that a durable composite mortar block could be constructed, the lower half of concrete up to the ground line, the upper half (6 feet) of wood block on end; this block to be anchor-bolted to the concrete.

This would secure solidity, would escape the excessive rigidity and would permit renewal of the woodwork at reasonable expense.

GUIDES.

Use the individual iron guide—guides without the wood bushing.

The stem will not be worn by rubbing directly against the cast iron guide with one-sixteenth of an inch play on either side. Oil

sparingly, say once a fortnight, by just touching the stem with waste moistened with a good quality of machine oil.

There are iron guides with wood bushings, but I have never seen one worth buying. It would be well to have the cap-piece of malleable iron, and the bed-piece should be 2 inches thick to avoid breakage.

With the old-fashioned oak guides there is too much friction, too much wear from burning. After a few months the shoe will not center on the die.

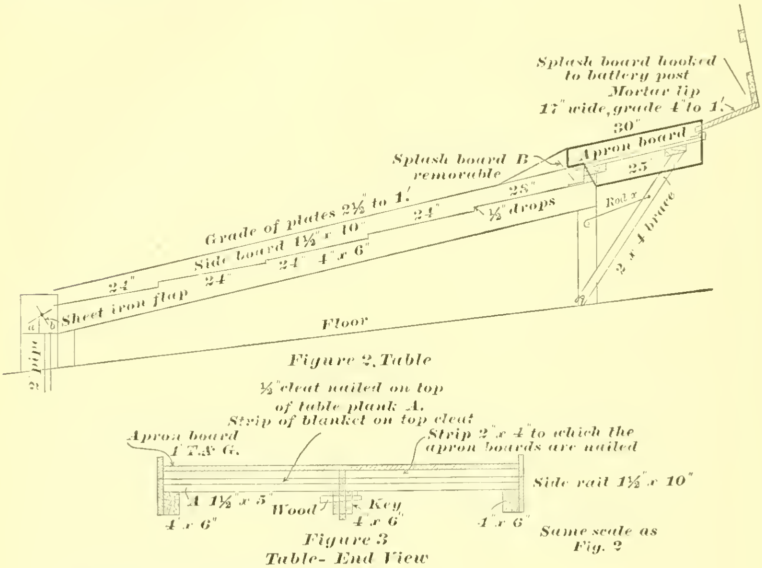


Table to be made of sugar pine, half seasoned.
4 table plank 1½″ x 24″ x 5′.
1 " " 1½″ x 28″ x 5′.
Strip of sheet iron 4″ wide under splashboard B; another 6″ wide under lip to prevent scour of plates.

The apron board 30″ x 5′ fits snug upon main table and is held ½″ away from the mortar lip by brace. The key holds it tight upon main table. Apron board removable. Unhook rods and take out braces. A 2″ x 4″ brace on each end of the apron board.

With the individual iron guide the stems will keep cool. With the oak guide the stems are always warm, and often hot. Heat means friction.

SCREENS.

I prefer the tin, costing ¼ cent per ton crushed. Neither Russia iron, brass wire nor steel can compete with this. Put strips, ¾-inch wide, of $\frac{1}{32}$-inch cheap rubber sheet packing between the tin and the wood frame, and you will at least double the life of the tin screen. Before using burn off the tin over a clear forge fire; just heat to redness, keeping the screen moving to and fro over the fire. This anneals and toughens the iron.

The three commercial sizes are: No. 0 = No. 8 needle, 441 holes to square inch. No. 1 = No. 7 needle, 324 holes to square inch. No. 2 = No. 4 needle, 225 holes to square inch.

No. 3 is too coarse for quartz.

If manufacturers would punch a size between the No. 0 and No. 1, and also a size a trifle coarser than No. 2, the range of tin screens would cover nearly all cases of quartz milling. The screen should have a selvage finish at both ends.

LINERS.

Use mortar liners, removable at every clean-up. The main back liner, instead of being in one piece, should be cut so as to give a lower piece of same width as the front liner.

SKYLIGHTS.

Nearly every large mill is dark in the middle; none need or should be. Builders depend too much upon side-wall windows. One skylight in the roof is better than four side-wall windows. Fig. 4 shows a cheap skylight, set flush with the shakes, which I have used successfully even in heavy snow countries on half-pitch roofs. The glass was ordinary 21-ounce plain. It does not leak, and the snow slides over it. Whitewash the walls and ceiling. Have a well-lighted mill day and night.

WARMTH OF BUILDING.

The plate and concentrator rooms should be built so as to be warm in the winter season. Never have a drafty mill. Icicles do not aid plate amalgamation. A few dollars spent in tarred paper on the walls will be a wise investment in cold countries. A generous stove, with a couple of hot-air drums 10 feet long by 30 inches in diameter, will prove economical of wood and keep a 20-stamp mill building comfortable and fit for amalgamation.

Light and warmth are not luxuries; they are the necessaries of the business.

TABLES.

Tables should be heavy and solid. Flimsy tables, made of thin boards and light scantling, get out of true. Figs. 2 and 3 show a table fastened to the floor. This form has advantages over the rolling table. Ordinarily, 12 feet long by 5 feet wide will suffice. Ten feet of this is nailed to the floor. The 30-inch apron is removable to allow setting in shoes and dies.

The frame is of three pieces, 4 x 6 inches by 10 feet, dressed on the upper edge and notched down ½ inch every 2 feet. The boards are 1½ inches thick, 2 feet wide, 5 feet long, dressed on

upper side, edges and ends. After dressing true, cross-plane the board so that there shall be a fall of $\frac{1}{16}$ inch from ends to center. Each board is butted snug to the one next above it and nailed or screwed to the 4 x 6-inch, the ends of the boards being flush with the outer edge of the outside 4 x 6-inch. The side rail is a plank $1\frac{1}{2}$ x 10 inches nailed against the side of the 4 x 6-inch, and forming a tight joint against the ends of the boards. To prevent leaking, bruise the edges of the boards with a blunt chisel, the blade 2 or 3 inches wide and $\frac{1}{4}$ inch thick. As soon as the table is wet these bruises swell.

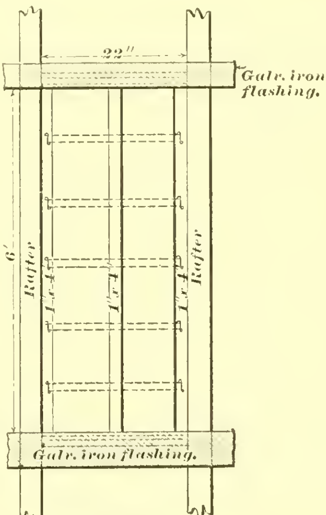


Figure 4.

Dotted lines show glass, 21 oz. plain, overlapped and kept in place by galvanized hooks, Putty under the glass.
Finish with strips of $\frac{1}{32}$ sheet lead flashing extending over the rafters and under the shakes.
The sash frame of rough 1″ x 4″ nailed to rafters.

At the foot of the table, Fig. 2, is a double drain box with sheet iron flap. While the mill is running the pulp flows into box *a*, thence to concentrators through a 2-inch pipe, the end of the pipe projecting $\frac{1}{2}$ inch above the bottom of the box *a*, thus forming a sufficient quicksilver trap. When brushing up the flap is lowered and the washings go over into box *b*, whence they overflow through notches into box *a*.

These double drain boxes will, under careful milling, recover \$25 to \$50 per month in amalgam which would otherwise be swamped in the concentrates or lost in the canyon. Under slipshod milling this box catchment might easily pay the mill payroll. This for twenty stamps.

Fig. 2 shows the arrangement of the splashboard.

By using a lip plate 17 inches wide, set on grade of 4 inches to the foot, there will be no clogging with sand and sulphurets, and the amalgam catchment will be heavy. Foundries ordinarily cast a mortar with $1\frac{1}{2}$ inches to foot grade on the lip. This will surely clog and prevent the amalgam from catching on the lip plate.

Let the pulp drop from the mortar lip (usually $1\frac{1}{2}$ to 3-inch drop) upon a sheet iron strip 6 inches wide, whence it flows upon the copper plate. A drop of over $\frac{1}{2}$ inch will scour the silver. Under the splashboard B a 4-inch strip of sheet iron is set over the plate to prevent scour.

LAUNDERS.

If of wood, let the launders be V shape, set to grade of $1\frac{1}{2}$ inches to foot.

ROCK BREAKERS.

Every mill should have two rock breakers, one coarse and one fine. Set the jaws of the coarse breaker 4 inches apart, so that a sledge can slide through, thereby avoiding the breaking of the pitman or side rods. Dump all the ore, coarse and fine, as it comes from the mine, directly into this large breaker. The mixing of fine with coarse ore prolongs the life of the jaws. The crushed ore is to pass over a grizzly; the fine going to the feeders, the coarse to be crushed in a second breaker. Manganese is the most durable for jaws and for mortar liners.

GRIZZLY.

Grizzlies often give much trouble by clogging, the rock building against the thimbles. The most satisfactory that I have ever used is made of 12 or 16-pound T rail, downside up, bars 6 to 8 feet long, $1\frac{1}{4}$ inches apart, at an angle of 42° to 45°, the lower end of the rails rolled over, as in Fig. 5. If not over 8 feet long it will be unnecessary to use a middle bar with its thimbles. The steep grade will give a fine product, and there will be only occasional clogging.

So much for the working tools. Select a mill site with plenty of fall; not less than 55 feet from track level to concentrator floor; better 75 feet. Heavy duty is exacted. Machinery is sure to break, therefore the working parts must be accessible.

MILLING.

I hold fast to four central ideas: First, on free gold ores the mortar has the two functions of crushing and of amalgamating. Second. on ores running less than $12 per ton the method used

must be such as to extract practically all the recoverable gold. (We will not now discuss $40 ore.) Third, if the ore is hard enough to require a rock breaker, build a heavy stamp mill, otherwise you may use one of the various rotary mills. Fourth, do not try to economize on rock breakers. It is the cheapest initial crushing; one to the mill is not enough.

There is a good deal said nowadays about high duty of mill,—*i.e.*, large crushing. I believe in high duty consistent with full

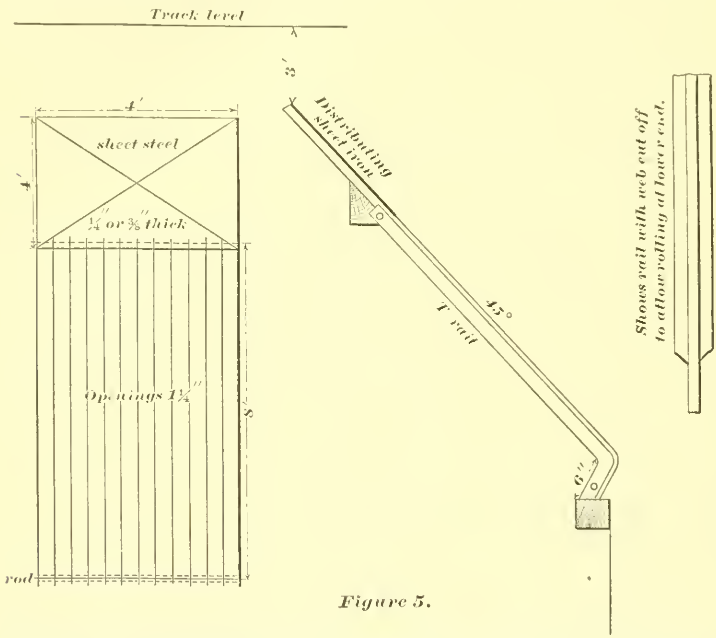


Figure 5.

Grizzly. To screen ore that has already been crushed in large breaker if mine produces coarse chunks.

recovery of the gold, but I cannot indorse a given type of mortar merely because it is a rapid crusher. High duty should mean low tailings.

The narrow, straight-back mortar, with low discharge, is not a new idea. The foundries are full of old patterns of this type. All our cement gravel mills are so built, but it is not enough to crush rock; one must also catch gold. High-grade tailings result from the sacrifice of amalgamation to crushing.

Taking up now seriatim these four captions:

The mortar has the two functions of crushing and amalgamation. Gold amalgam is a slippery eel; it rolls and floats unless fairly treated. Give it opportunity and it will settle in the mortar. It is not so hard to catch fine gold inside the mortar if the mortar

is built for that purpose. The limit of crushing in a given mortar must be measured by the percentage of inside amalgamation, except, however, on ores carrying values of \$1.00 to \$1.50 per ton of fine light gold. The aim should be to increase the inside catchment above 60 per cent. The tendency of stamping is to combine the gold with the mercury. It is natural that this amalgam should stay inside, and it will unless the millman expels it in his struggle to secure a high crushing duty.

Extract practically all the recoverable gold. Whoever has used quicksilver has lost gold. Whoever has crushed ore has had uncrushed particles of sand carry some atoms of gold stowed away inside the particles. Therefore, tailings must assay something. It is a commercial question. You may be able to afford some loss in order to get through a larger tonnage. To illustrate:

Preparing a tailings sample for assay by screening through a 40-mesh screen, we find that 2 per cent. of the sand rests on the screen, and the fire assay shows values of 5 cents or 10 cents per ton in the fine sands and \$1.50 per ton in the coarse.

The results may be tabulated:

98 tons @ \$0.05	= \$4.90	or @ \$0.10 =	\$9.80
2 tons @ 1.50	= 3.00		3.00
100 tons	= \$7.90		= \$12.80

i.e., \$0.08 to \$0.13 per ton.

I am quoting actual results, not giving theories. The crushing was at the rate of 3 tons per stamp through a No. 2 tin screen.

This 2 per cent. coarse sand could have been saved by using No. 1 tin, but it would have been at reduced crushing tonnage, and would have come close to the sliming danger.

I call this extracting practically all the recoverable gold, and to increase this crushing to $5\frac{1}{2}$ tons and the tailings to 75 cents per ton would be business suicide, whether there were 10,000 or 10,000,000 tons in the mine.

Use stamp mills on quartz. Some one will probably invent a better machine than the California quartz mill for crushing rock and catching gold. It has its faults, and yet its much-condemned sliming tendency is too often the fault of the millman. It is simple, relentless and conscientious, with fewer faults than cling to many of its operators.

It is easy to stir mud, but if you have rock to crush build a heavy California stamp mill, with the shoe $9\frac{1}{2}$ inches and the die $9\frac{3}{4}$ inches diameter; the whole stamp weighing 1100 pounds, $10\frac{1}{2}$

inches from center to center of stems. The ends of the mortar, after the liners are in, should be flush with the screen opening.

I have heard more than one man assert that his ore did not require a heavy stamp, but I have always found that such men had never tried the two weights on the same ore. If the ore at one mine happened to be harder than at another they would endeavor to effect a cure by giving more drop to the light stamp. If the rock still resisted and the stamp bounced they would settle back on the excuse that they had very hard ore.

I have had an 850-pound and a 1100-pound stamp on the same line shaft and on identical ore. The former crushed $1\frac{1}{4}$ to $1\frac{1}{2}$ tons per stamp, and the latter 3 to 4 tons per stamp. The light stamp could not do the work, no matter what drop I gave it.

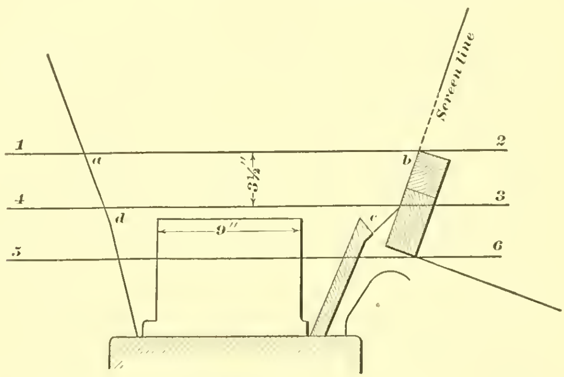


Figure 6.

Now, then, how fast shall we run this heavy mill? What drop shall we give it?

I want a heavy stamp because I do not want to waste time breaking rock. I want a shoe and die of large area, so as to embrace many pieces of rock at every blow. If you reduce the crushing area from $9\frac{3}{4}$ to 8 inches you are compelled to make up the deficit by speed or by a long drop.

Bring a sledge upon a bowlder. If you don't break it, you make the next blow harder, but you don't hit oftener. Probably you will strike lower. You accomplish your result by muscle, not by agility.

So it must be with a stamp mill. Stamp crushing is not a question of spalling rock; its object is to crush and amalgamate ore that has been, as it were, already spalled by the rock breaker.

I am now running a mill upon unusually tough, hard ore; first-class road metal some of it. With a speed of 92 to 94 and a

drop of 6 to 7 inches, a 1100-pound stamp will crush about 80 tons in twenty-eight days and save all the gold. Increase the speed to 100 or 102 and the drop to 8 or 9 inches, and this same stamp will crush about 110 tons in twenty-eight days and by no means save all the gold.

So, then, my rule is to get weight and area of stamp, so as not to waste time, and to drop as the tailings assays dictate.

High speed means more wear and tear, hot boxes, greater percentage of breakdowns. If you can reach the limit of profitable amalgamation by a slower speed, why not do it?

I have never run a stamp heavier than 1120 pounds, and I regard that weight as sufficient.

I have found it easy to crush more than I can amalgamate. It is for this reason that I am unable to give assent to the practice of installing a system of rolls and crushers so as to deliver a cracked-corn product to the stamps. For some mysterious reason there is benefit to amalgamation by churning rock in a mortar. I am no sufferer if it does take a little more time in the making of the butter. If the mine needs more stamps, buy them.

Before a 5-stamp battery, 5 feet width of plate seems to be the practical limit. Six feet is too wide, and 5 will give better results than 4.

I have tried a launder before ten stamps, the pulp being thence passed to three tables, each 4 feet wide. This was a failure. By no adjustment of gates and water could even distribution and flow be obtained. One table was all sand, and another all slimes. The wave, the crescent bow, was not there.

Provide rock breakers liberally. One breaker to the mill is the rule, and ordinarily this means that much of the ore going into the feeders will not pass a 2½-inch ring. It would not cost much to cut this product to 1-inch ring size, and a very noticeable increase in crushing will result. With a 1-inch ring product there will be fewer broken stems and consequent delays.

The rock-breaker end of the mill is too much neglected. One is not enough to any mill. On the other hand, I see no gain in going to the other extreme of too minute rock-breaker crushing.

The following rules are suggested:

Catch the gold close to the die.

Don't use chock-blocks or inside coppers.

Don't slime by too fine crushing.

Don't crowd tables with too much pulp.

Don't sluice the pulp over the plates.

Don't add water outside the mortars.

Don't be afraid of steep grade to tables.

Use no distributing boxes.

Don't turn all the pulp on one-half the plate area when brushing up.

Don't scrape plates with chisel or rubber. Rub up with a cotton cloth and tepid water. Lip plate, however, is scraped off monthly with a chisel.

Feed quicksilver so carefully that never a free globule appears on the plates.

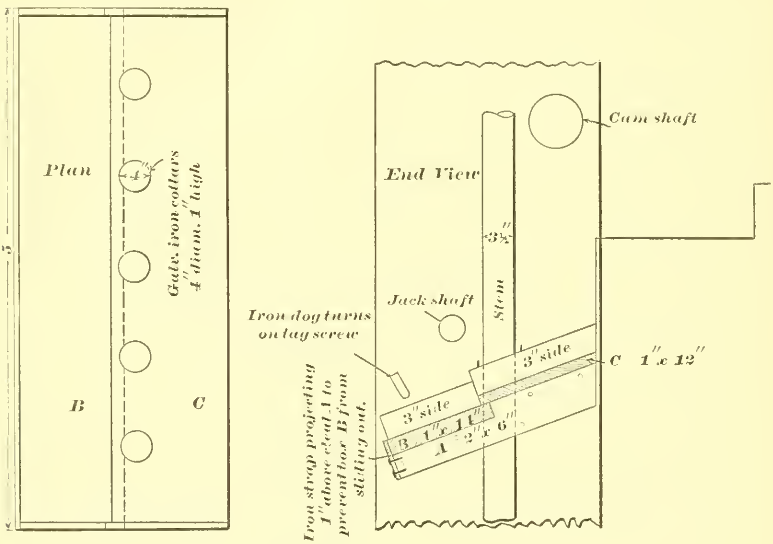


Figure 7.

Grease boxes over mortars.

Two cleats, A, are lag-screwed to the battery posts. The boxes, B and C, 3" deep and lined with galvanized iron, rest upon these cleats and fit snug between the posts. C is screwed to cleat A. B is removable and is held down by the iron dog.

The galvanized collars prevent grease from working down upon the mortar housings.

Feed low,—*i.e.*, regulate the feeder so that the shoe is kept just cushioning on the die.

Run the batteries with the splash, and not with the wave motion,—*i.e.*, lift the shoe above the water at every blow.

Use automatic sampler on tailings.

Avoid the use of acids and cyanide on plates; common lye will cut grease.

Keep the quicksilver clean by retorting, and then washing well with dry lime; follow this treatment with thorough washing in clean water.

Use well-silvered plates. When they turn green, replate them; and don't waste time and gold over nostrums.

Catch the gold close to the die. This requires a roomy, rather than a narrow, mortar. You can't churn butter in a teacup, and you must churn if you want to amalgamate. I am now using two styles, both 1100-pound batteries. There is no difference in crushing, but the mortar shown in Fig. 1 invariably makes the larger inside catchment. The other mortar has a straight back.

Whenever I neglect my inside catchment the tailings run up. Set the discharge too low and the mortar will throw out on the plates. It is the province of the plates to catch the fine gold, not the coarse. Coarse gold will roll down hill, and the table is a down-hill proposition. Coarse gold makes good-sized bits of amalgam, and the natural habitat of these is inside the mortar.

On quartz the discharge must not be less than $5\frac{1}{4}$ inches at the start,—*i.e.*, $5\frac{1}{4}$ inches depth of water measured from the top of the die to the bottom of the screen opening. Starting with this, you will soon have $5\frac{3}{4}$ inches discharge. We will say now that the wear of the die is 2 inches in twenty-eight days. This would mean $7\frac{1}{4}$ inches discharge at close of the run, and would diminish the crushing.

To cure this make one screen frame with 3-inch strip on bottom and 2 inches on top edge; make another screen with a 1-inch strip on bottom.

As the run progresses you can change and turn screens so as to preserve a practically uniform discharge.

The drop is regulated by the tappet.

There is no harm in using a $6\frac{1}{2}$ to $7\frac{1}{2}$-inch discharge. But there is no gain to amalgamation, and you diminish the crushing capacity of the mill. In other words, work so as to obey the injunction, "Get through all possible consistent with full recovery of the gold."

Some interesting experiments were made at the Utica and Gwin mines on mortar shapes for 900-pound stamps. The back of the mortar was straightened to 77°. At the discharge line the distance from shoe to back is $2\frac{1}{4}$ inches, and to screen $5\frac{1}{2}$ inches. It was found that this mortar would crush 5 to $5\frac{1}{2}$ tons to the stamp on Utica and Gwin ores, whereas the wide mortar crushed 4 to $4\frac{1}{4}$ tons; this with No. 2 tin.

I attempted to apply these lines to an 1100-pound mill, but did not increase the crushing; and can only attribute the failure to the fact that the heavier and larger shoe makes a more vicious splash. You cannot bring the screen closer than $7\frac{1}{2}$ inches to the shoe. On identical ore the mortar shown in Fig. 1 will outcrush this straight-back Utica mortar, because of the greater weight and shoe area, and it is a better amalgamator.

No chock block or inside coppers. A copper plate in the mortar will attract amalgam. But copper is no better magnet than is amalgam itself. Start a bed of amalgam in some secure cranny around the dies, and you will have as eager an ally. Grooves in the liners only shorten the life of the liner.

Everyone who has used a chock block has seen it build with amalgam, and has also seen it scoured red, in whole or in spots; scoured, we are told, accidentally. Let us dissect this "accident."

Every battery is liable to be filled up with sand. Feeders fail, faucets choke, millmen yawn or are busy elsewhere; no matter the reason, true it certainly is that every battery fills up sometimes. It is this fill of sand that scours the chock block. Amalgam, once scoured off, is rebellious metal. It is round and hard; it gets out on the plates, where it rolls and tumbles, scorning to stick, content only when it lands in the concentrates or in the canyon. If in the canyon it is lost for all time. The millman blames the accident he himself has concocted, *for the chock block lies within the zone of scour.* Study Fig. 6.

Particles of gold and amalgam are flying about within the area *a, b, c, d.*

These particles can be attracted upward to the chock block or downward below the line 3-4, as you please. If you use a chock block they will fly to it. If you don't they will sink around rocks. Every particle lodged will attract another; soon it will be a mass. But note the difference. The chock block lying within the zone of scour 1, 2, 3, 4, your caught amalgam is in danger of loss. The zone 3, 4, 5, 6 being below the line of scour, your caught amalgam is safe till clean-up day. Millmen may sleep, faucets clog, feeders buck; your amalgam is safe.

Repeatedly do I find the entire front of my mortar, below the line 3-4, one mass of amalgam, in cakes $\frac{1}{4}$ to $\frac{5}{8}$ inch thick; this on \$5 to \$7 ore.

Take the year through, and you will catch more gold inside without chock blocks than with them.

Another important advantage is that, in case of overfeed of quicksilver, this excess will be safely absorbed by the mass of amalgam around the dies. Excess of quicksilver on a chock block is fatal: it sloughs off the amalgam.

When one considers the varied duties of the millman, and the sudden variations of gold ores, there is full warrant for abandoning the chock block.

Don't slime by too fine crushing. Especially vicious is this practice on slate ores. The correction can be located only by assaying the tailings through different meshes.

If you slime you are also wasting power by dead—*i.e.,* useless—stamping.

Don't crowd plates with too much pulp.

Don't sluice the pulp over the plates.

Don't be afraid of steep tables.

No distributing boxes.

Don't add water outside the mortar.

These five rules may be treated together.

It is not easy to set down in words just what the conditions of the pulp should be. It is a question to be determined by the eye.

If you will let the mind dwell upon these negatives some idea of my meaning may be realized.

Plate amalgamation and ground sluicing are different arts. Gold is caught on plates because gravity settles the metal to the silvered surface. Therefore, don't be in a hurry to get rid of the sand, and don't throw obstacles in the way of the laws of gravity. Gold and mercury have their full share of specific gravity, but reverse the conditions and you easily offset this factor.

The pulp must not be too thick on the plates; you don't want a double deck of sand. Furthermore, there should be an even flow of water over the entire plate area. It is for this reason that the center of my plate is $\frac{1}{16}$ inch below the edges. Batteries tend to a greater discharge in the corners than in the center. It is a common sight to find a rush of water 4 to 6 inches wide along both edges of the table; one-fifth to one-fourth of the plate area is overflooded.

Many mills have tables 24 feet long, with no break in grade. Drop a cork chip at the head of such a table and at the same instant another chip at the middle. You will find that the second cork will travel its 12 feet in less time than the first one, because the velocity of flow must be accelerated on such a table. If the flow is correct for the first 12 feet, it must be wrong for the second 12 feet.

It goes without saying that tables should be of uniform width from top to bottom.

The sand should move over the plates slowly and evenly. The water will go in waves or pulses, while the sand below it will be kicked along by these successive waves, not moving any faster over the last 2 feet than it does over the first 2 feet of the table. Between the waves the sand almost, but not quite, comes to a standstill. Note this point especially: The sand is kicked along; it must never be swept along by a heavy flow of water.

Have a wave and use it. It is these successive kicks that tumbles the sand about. Before the last plate is reached the gold is kicked into its proper place,—viz, to some sticking point. The

$\frac{1}{2}$-inch drop every 2 feet assists the process in two ways: (a) The drop bowls the particles over; (b) it prevents acceleration of flow.

With this thin, carefully regulated flow and a sticky, pasty plate good amalgamation will be had.

One reason for the excessive use of water, so common, is that the table has too little grade.

The millwright turns over a table $1\frac{1}{4}$ to $1\frac{1}{2}$-inch grade to the foot. It should be $2\frac{1}{2}$ to $2\frac{3}{4}$-inch.

Don't be afraid of steep grades, for it means less water and clean table; no danger of scour.

Distributing boxes are an abomination. The holes get plugged up. They incite the millman to careless use of quicksilver when rubbing up. They are traps to gather quicksilver, and let it out in lumps on the plates. They don't distribute pulp as evenly as the plain splashboard (Fig. 2).

Globules of free quicksilver on the plates should never be tolerated. If there is a distributing box the millman can lay the blame to the box. Take away the box and rob him of his excuse.

Don't add water outside the mortar. One needs just the same amount of water inside the mortar as out, and I use just enough water in the mortar to move the pulp properly over the plates. No reliance can be placed upon stated formulæ of so many gallons per ton of ore.

The quantity of water is vital, and nine millmen in ten use too much.

Don't turn all the pulp on half the plate area when brushing up.

We have all seen the 4-foot plate with partition strip in center. The battery is not hung up when brushing the plates, but all the pulp is turned to one side of the strip while the men are working on the opposite side.

It seems to me there can be no logical defense for this custom. If 4 feet width is needed at any moment, it is for all the moments. To confine all the flow to 2 feet width must inevitably scour. The only excuse urged is that it does not pay to hang up. I hardly think it pays any better to scour; the richer the ore the greater the loss. Build another battery if the mine will stand it. The average mine will survive the shock of a little hanging up.

The champions of the never-hang-up theory seldom, if ever, sample tailings when brushing up. They don't know their own losses. It is a well-known fact that upon ore of only $8 value the plates, just before brushing up, will be plentifully sprinkled with coarse bits of amalgam barely hanging on against the flow. I suggest, by way of proof, that three tailings samples be taken

from the 4-foot plate width within the ten minutes preceding the rubbing up, and then three samples from the 2-foot plate width during the ten minutes of rubbing up. Do this for thirty days, making careful assays of all the samples. Note the per cent. of assays abnormally high, due to particles of amalgam.

It is not sufficient to reply that what is lost in amalgam is recovered in the concentrates.

Every concentrator passes more or less of amalgam and mercury over into the tail race.

Don't scrape main plates with chisels.

Allow no globules of free quicksilver on plates.

It is essential to keep a well-silvered surface, sticky and pasty. The apron plate may require replating every three or four months. The lower plates should wear several years. The cost of replating varies with the ore. I have found it amounts to from 1 to 1½ cents per ton crushed, using a plating of three ounces silver per square foot of plate.

Every morning I take off the excess of amalgam, but never skin it closely. Rub up with a piece of cotton domestic several folds thick, sprinkling the plate with quicksilver from a small shaking bottle. I have seen used a beer bottle with a quill through the cork, but this is malpractice. Use a small vaseline jar with a piece of cotton tied taut over the mouth, and have clear, tepid water in a kettle to dip the rag in frequently. Rub the plate briskly and thoroughly, being careful every day to remove all blisters of amalgam. These blisters eat out the silver, and therefore should not be permitted to form. In cold weather they are especially troublesome. If they stick too tight for the rag, they may be gently scraped off with a piece of No. 24 stovepipe iron shaped like a flat scoop 2 inches wide. Do not use a steel chisel. Finish with a final light sprinkling from the jar and thorough rubbing with the cotton rag; then brush over with a whisk broom.

The lip plates are never softened with quicksilver, but are every morning brushed off, or rather scrubbed off with the broom, to clean out the sulphurets. The lips will stand a good stiff brushing daily.

At 4 o'clock P.M. and at midnight my plates are again rubbed up, but no amalgam is taken off at these times. It therefore takes only a few moments for these two rubbings. My running time on a 20-stamp mill is twenty-three hours daily, because of this careful plate treatment.

There are never any globules of free quicksilver on the plates, top or bottom. If the ore is lean we feed less in the battery, and

the rubbing up is so carefully done that it never leaves drops of quicksilver on the plates.

The quicksilver fed is weighed at every shift in troy ounces, and a daily record is kept. I never weigh out an allowance to my millmen. They know what is expected, and careless work reveals itself immediately on a plate. At clean-up there should be little or no free quicksilver in the mortars around the dies.

Battery water at 55° F. will give good results. It is essential to avoid sudden changes. I never saw a reliable mechanical heater. Perhaps, where oil is cheap, the incubator lamp would work.

I rely upon keeping the plate room warm because I am afraid of the sloughing off of amalgam, which inevitably follows a sudden rise of 20° to 30° in the temperature of the water. I am still studying the problem of keeping the water uniformly at 65°.

AUTOMATIC SAMPLING.

The custom of sampling tailings with a dipper by hand every half-hour, more or less, has but little to commend it.

It is to the owner's interest to know exactly what the tailings assay. It is to the millman's interest to keep the tailings low.

The hand sampler will soon learn how to sample judiciously, from his point of view, but no one can coach an automatic sampler driven by machinery.

It is absurd to take off the sample by hand from the tail of the vanner.

Several kinds of excellent automatic samplers are in use, but I will not take the time to describe them. However the sample be taken, it should be evaporated to dryness for the assayer. Do not pour off the clear water; you may use a siphon.

CLEAN-UP APPARATUS.

To clean up I use a wooden trough 5 x 2 x 2 feet; a man with the hoe; a 49 rocker, 4 feet long by 16 inches wide; a clean-up board 5 feet long by 12 inches wide, with 3-inch side rails, covered with a silvered plate; a buck and a wedgewood mortar; a small iron screen $\frac{1}{8}$-inch mesh.

Into the trough throw all the mortar dirt; sprinkle freely with quicksilver; turn in boiling water; then hoe the mass about thoroughly with hoe and strong four-tined rake, so as to break up all lumps. The dirt is then rocked out, and the resultant amalgam, iron scraps and fine sands dumped upon the clean-up board, and the sand washed out with a hose stream. The iron is taken out by magnet. Grind the amalgam a few minutes in the buck mortar;

rewash on the board, giving a final bath of quicksilver in a wedgewood mortar to skim off the dross. To make sure there are no lumps or bits of iron, copper or brass, strain through the $\frac{1}{8}$-inch screen and regrind the lumps.

By this process two men will in two hours clean up a 20-stamp mill and leave not over $50 in the sands.

These sands are, of course, put back in the batteries at the following run.

I would clean up a 100 or a 500-stamp mill by the same process, except that the mixing would be done by what the macadamizing men call a "rattler" or revolving trommel; rattler and rocker to be driven by power.

Clean-up barrels and pans flour the quicksilver, and thereby entail unnecessary losses of gold.

The clean-up room should have a cement floor. All wash water should pass into settling boxes or tanks.

CONCENTRATORS.

Concentration is too broad a question to be discussed here; so much depends upon the characteristics of the metals and the gangues.

In too many mills the crew is inadequate, so that both batteries and vanners suffer alternately as the solitary millman trots up and down stairs vainly attempting to do the work of several men. I never saw a dozen belt vanners in any mill all working right for over five minutes at a time.

For the average gold mill the concentrator should not be oversensitive. There is a wide difference in this respect between the various belt vanners. Don't pay much heed to the advertised competitive tests.

It is because of their extreme sensitiveness to variance of load or water that I am disposed to think that the reign of the belt vanner is about over.

What is wanted is a machine that will not go awry at every little variance of pulp.

The belt vanner seems to require some experienced hand camped alongside it all the time. In that way the makers conduct their misleading competitive tests.

The Wilfley concentrator requires a heavy load—20 to 40 tons—to do effective work, consequently there would seem to be no room for it in a 5-stamp mill. Possibly a smaller table would scale down to, say, a 10-ton load. Manifestly, any concentrator

with so wide a range as 20 to 40 tons will not be going wrong every five minutes.

It is worthy of investigation, and it is idle to object that it has no belt.

COSTS.

To close, I present some details of cost per ton in a 20-stamp mill, based upon a year's average,—16,000 tons,—with freight at $1.10 per cwt. from San Francisco; wages of amalgamators, $3.50; of rock-breaker men, $3:

Water power: rock breakers	$0.0102
Water power: batteries	.0884
Labor, all, including repairs	.2862
Shoes, dies, mortar, liners	.0721
Oil: light and lubricating	.0131
Replating	.0100
Sundries	.0024
Firewood (4600 feet altitude)	.0081
Rock-breaker jaws, tappets, bosses, extras	.0130
Quicksilver loss, 0.145 troy ounce per ton	.0052
Total per ton crushed	$0.5087

Quicksilver loss includes the mechanical losses from retorting, cleaning up, etc. The tailings ran from 5 to 20 cents. The ore at the monthly clean-ups ran from $4.75 to $10.25 per ton.

RECAPITULATION.

Use a stamp mill because no better machine for the purpose has been invented.

Use a heavy stamp because it won't waste time, and can be run slow enough to save wear and yet fast enough to churn, and therefore amalgamate.

Have large shoe and die areas, so as to embrace plenty of rock at every blow.

Crush and also amalgamate, the limit of your crushing to be taught by the tailings assays.

Extract all the practically recoverable gold. If more stamps are needed, build them.

The speed and drop suitable can be determined only by assaying tailings.

Catch the gold close to the die.

Renounce chock blocks.

Don't slime by too fine crushing.

Beware of too much water.

Don't crowd the plate with too much pulp.

Have the plate sticky and pasty with amalgam, and never dripping with quicksilver.

Use a broad, steep plate, and hang up when rubbing up. Note the use of the word rub, not wipe. Put elbow grease, and no other, on the plates.

Don't be parsimonious about replating.

Sample automatically.

Keep the battery water temperature not below 50° F.; better at 65° or 70°.

ON THE NEED OF EDUCATION OF THE JUDGMENT IN DEALING WITH TECHNICAL MATTERS.

By George W. Dickie, Member of the Technical Society of the Pacific Coast.

[Read before the Society, December 7, 1900.*]

Of all teachable things, the education of the judgment receives the least attention, while its importance is supreme. I do not know of a single university that has a chair of common sense, and in trying to reason out why this so important endowment is not taught I can think of but one reason, and that is the impossibility of finding a man to fill such a chair.

Men in all professions are therefore left to acquire this most important part of their education as they acquire practical experience, and in most cases with as little success.

It is an unfortunate condition with us that we are nearing the end of our work before we realize how important a factor judgment is in all questions of importance that come before us in our everyday experience.

Self-education in the matter of judgment is a life-long mental discipline. One of the most important points in this process is very difficult to deal with, for every time it comes up it involves us in an internal struggle which equally affects our vanity and our ease.

This point consists in the tendency to self-deception in regard to the result we wish for. For any one who is not brought daily to the necessity of self-correction in regard to this tendency, it is impossible to realize how all-powerful the tendency is, and how unconsciously we all yield to it. How eager we all are to seek for such evidence as may be in favor of what we want the result to be and to disregard any evidence pointing the other way. We receive as friendly that which agrees with our preconceived notions, and resist and dislike that which opposes them.

In fact, the inclinations we exhibit to receive and to act upon any report or opinion that harmonizes with our preconceived notions can be compared, in degree, only with the incredulity we entertain toward everything that opposes them. And all this goes on unconsciously, while we honestly believe that our judgment is entirely free and unbiased.

It is my purpose to try, in as simple and direct language as I am able to use, to point out some of the ways in which we fail to exhibit sound judgment in dealing with the engineering problems that confront us every day.

*Manuscript received December 13, 1900.—Secretary, Ass'n of Eng. Socs.

In my work, how do I suffer from lack of judgment on the part of myself and those connected with me, and how could much of that suffering be avoided, thereby reaching results with less waste of labor and time? This is an inquiry worth making, even if the answer be not quite satisfactory.

There is fast growing up a system which, if I understand the direction in which it is moving, proposes to dispense with the necessity for the exercise of judgment in dealing with everyday engineering problems. Young men without experience, and who have never had the chance to acquire an educated judgment, are, as a rule, put in charge of very important work, and a set of instructions is provided for their guidance, which instructions are supposed, if rightly carried out, to obviate the necessity for any exercise of judgment on the part of the person in charge.

Those of us who are carrying out large contracts with the Government and with some public companies find it hardly possible to get anything decided by sound judgment based on experience. I have often tried to reason from my own experience with young inspectors of work, but that kind of reasoning is not now admissible. Printed instructions are produced, with the intimation that these must be adhered to in every particular, the inspector having no discretion in the matter. I have often traced these printed instructions back to their source, and found the author to be a man whom I would not like to trust with doing the work covered by them.

In mechanical engineering and kindred business, such as shipbuilding, the great bulk of the designing is done by the contractor, all working plans being prepared by him. He is also held responsible for the result; yet all his plans must be submitted to a young and, from the very nature of the case, inexperienced inspector, who, however clever he may be in solving theoretical questions relating to the device in question, has never had to make those things himself and to be responsible for their working after being made, and for their costing no more than he said they would cost before he began.

Now, the young inspector reads in his book of instructions, generally in a preface, that the object of printing these instructions is for the proper protection of the interests of the Government.

In a decision by the Judge Advocate of the United States navy, I read the other day that the aim and intent of the wording of the specifications and contract for the building of a warship were solely to protect the interests of the Government.

Now, my idea has always been that the object of the specifications and contract, when fully carried out, was to produce the best

possible warship of the kind specified; that there were two parties to the contract, and that the interests of one needed protection just as much as the other. The language used in the decision mentioned shows how difficult it is for an inspector to use sound judgment, even if he has it at his command. When a plan is presented to him by which you propose to carry out the object of the specification, he looks at it with the distrusting notion in his mind that you have used what skill you possess to design this part of the work as cheaply as possible, and that it is his business to stand between you and the object of your desire; and he will not reason with you as to the why and wherefore of your design without putting you on the defensive in regard to your own character instead of that of your design. And when he has found out where he can add something to your design, to increase its cost without spoiling it, he is very likely to do so, as he thereby tickles his own vanity by impressing you with his power and cuts you out of doing the thing with the simplicity and economy that you were planning for.

This shows the need of an educated judgment on the part of such an inspector. And of course it might be the other way. The contractor, in making his design, may allow his self-interest to rob him of all sound judgment, and his desire for a simple and cheap device may lead him into making something that would not properly meet the requirements of his contract. What is needed is an honest endeavor on both sides to cultivate the growth of a sound judgment that can decide technical questions altogether apart from the personal interests of the parties.

In no question is sound judgment, based on long experience, more necessary than in the many disputes that arise regarding workmanship and material. Here, where an educated judgment is most required, we find that self-interest and hard and fast rules interfere most with its application. When I look back over the many battles I have had with inspectors who demanded their pound of flesh when it could not possibly be got without blood,—sometimes all the judgment lacking on the one side, and sometimes on the other,—I wonder why we should continue beating the air over questions that with the exercise of a small amount of sound judgment would never be raised.

A good many years ago, while in the casting yard one morning, I noticed a propeller casting, a solid cast wheel which had, as many of them are apt to have, some gas checks across the back. I did not consider that the small defect should be any reason for condemning the casting. That was my judgment. Perhaps I was assisted in forming this judgment by a strong desire to save the

cost of another casting. When the superintending engineer of the company for which this wheel was made saw the casting, he promptly condemned it, and no amount of reasoning on my part could alter his judgment. There being no desire on his part to help his judgment to concur with mine, he would take no chances with a wheel having any visible defect. And he believed that my opinion was formed entirely on self-interest, while his was founded on the high plane of engineering prudence.

In this particular case I thought it worth while to test the foundation upon which each of us based our judgment. So I said to him, "Your company pays for this wheel 9 cents per pound, and it costs my company 6 cents. If I make another, we will lose 3 cents per pound instead of making 3 cents per pound. Now, I think that I am right in claiming that the slight defect in this casting is no ground for condemnation, but in order to save actual loss your company can have the present wheel for 6 cents per pound."

"Well," said he, "now you're talking reasonably. I will see our people about it and let you know." Within an hour this wheel was accepted and went into service, and, so far as I know, had a long and useful life.

Now, I myself might have acted just as this engineer did, but the transaction illustrates how much we are all influenced by our own desires in these questions instead of by sound judgment and how difficult it is to know when the decision is prompted by desire when we think we are exercising our judgment.

Our whole modern method of testing and inspecting materials is founded on the belief that the faculty of judgment in an inspector is a dangerous thing, and that all excuse for its cultivation must be eliminated from his mental stock in trade.

The other day I saw condemned and broken up a large bronze casting that had cost about $3000, because the coupons or test pieces showed less tensile strength than the specifications required. The casting itself was perfectly sound and very tough; in fact, admirably suited for the purpose for which it was made, and not the slightest doubt of its character was expressed by any one who saw it. Yet, because the test piece was required to show 55,000 pounds tensile strength per sectional inch and broke at 44,000 pounds, a great deal of labor and costly material was deliberately destroyed, the inspector claiming that he had no discretion, which means no judgment, to exercise; and, when the case was appealed to a higher authority, that authority, who could not see this good piece of work, entirely suited for its place in the structure and with ample margin of strength, simply sent to destruction with the

careless remark, written officially from the other side of the country, that the requirements of the specifications must be fulfilled.

You must not understand me to mean that physical tests are not very important in deciding the quality of material, but when applied without judgment they may result in great waste of both labor and material, for they do not present the whole case, even as to the character of the material of which the test pieces themselves are made.

We often have plates of steel where the test pieces, cut directly from the plate, will give fine results, say 60,000 pounds tensile strength and elongation of 30 per cent. in 8 inches, and will double over on themselves without sign of fracture, and yet the plate itself would break like glass in bending over a large radius.

I have cut test pieces right out of plates that would not bend at all, and the test pieces would double over on themselves without sign of fracture.

Not long ago I had a plate of Government material to bend on the press for a keel plate, but the plate broke hopelessly in bending. There was no other plate to replace it of material that had been tested and accepted for Government use, and the inspector would not allow any other plate to be taken for the purpose.

I, however, took a plate of steel for merchant work and bent it to the required form with no sign of fracture. We cut a test piece out of the broken plate, right by the fracture, and it showed 61,000 pounds tensile strength and 28 per cent. elongation, and bent over on itself without fracture. Then we took a test piece out of the plate that had been successfully bent to the desired form and showed 62,000 pounds tensile strength and 22 per cent. elongation, and it broke before it had completely bent over on itself.

Therefore the perfectly bent plate was not allowed to be used because the test piece did not meet requirements.

Here the test intended to guard against the use of unsuited material resulted in preventing the use of eminently suitable material; not because of anything wrong in the test, but through the lack of judgment in applying the result of the test to the desired end.

I could multiply cases—they are of almost everyday occurrence—where the lack of judgment in regard to the value of tests results in needless loss and in great delay in carrying out work.

Lack of judgment is often manifested in a demand for unreasonably strict compliance with a specification that makes no allowance for ordinary imperfections in all products, even of the most skillful workmen.

Not many days ago I had such a case to deal with in building a small marine boiler for the Treasury Department under a very

strict specification. I found that it would make better work to weld the plate forming the sides of the combustion chamber, as the seam was in the way of the stays as shown in the drawing. The inspector thought so too, so the plate was welded; but the slight waste in heating resulted in the plate being one-thirty-second of an inch thin at the weld. I did not foresee this, but the inspector discovered that the plate was slightly thinner at the weld, and, the specification requiring a certain thickness of plate, the work was suspended until a decision should come from Washington. The decision came in due course and in the usual form, instructing the inspector to require the work according to the specifications.

Now, if this had been made as specified, with a riveted joint, its strength would have been, say, 67 per cent. of the plate, while the welded joint gave 92 per cent. Yet, notwithstanding all this, the work was condemned and thrown away.

This loss did not result from any desire on the part of the inspector or his superior to cause loss to the contractor, but simply from a failure on their part to apply sound judgment to the question before them.

A plan or specification is an instrument to be used for the production of a certain piece of engineering work. The thing produced is the only reason for the instrument being brought into existence, and when once the instrument has served its purpose its value disappears.

Yet engineers engaged to apply this instrument are, as a rule (especially the young men), more intent on applying the instrument than in considering what the instrument may be doing, forgetting that the instrument can of itself produce nothing, and that if not applied with judgment it will produce only such things as the man that made the instrument could himself produce. But, when applied with the correcting power of sound judgment, acquired in the production of similar things with other instruments, it becomes pliable in the hand of a master, and the result is the combined power of the instrument with the trained judgment of him that applies it.

All technical men engaged in producing tangible things out of ideas expressed in our defective language, interpreted by some one perhaps better acquainted with words than with things, and whose judgment has not been matured by any intimate knowledge of the actual work that the specification he is to enforce is intended to produce, feel how hard it is to get their position understood, and how often they must do things against their better judgment for fear it may be thought that their own interest, and not their experience, is the foundation on which their judgment rests.

OBITUARY.

John H. Blake.

By Frederick Brooks and William B. Fuller, Committee of the Boston Society of Civil Engineers.

John H. Blake, youngest son of Thomas and Mary Lowell (Barnard) Blake, was born December 5, 1808, at the South End of Boston, near where the Cathedral now is. His ancestors lived in Dorchester, in the old Blake house, now kept as a historical museum in charge of the Dorchester Historical Society. It is at Dorchester Five Corners, recently called Edward Everett Square, a short distance from where it originally stood.

John H. Blake was educated in the Boston public schools, being in the English High School in 1821 in the first class that entered the school.

The earlier portion of his business career was connected with chemistry and mining. He established a laboratory at Jamaica Plain, Mass., for the manufacture of pure chemicals. He and his brother-in-law, Otis Everett, Jr., were in partnership as chemists on South Market street down to about 1837. He made a journey to Peru in 1835 for the purpose of investigating the niter beds. He surveyed the Atacama region and explored an ancient cemetery at Arica, and made a collection of mummies and other interesting objects, which has been, since 1878, in the Peabody Museum of American Archæology and Ethnology at Cambridge. Drawings and descriptive notes by Mr. Blake were published in the second volume of the reports of the museum, pages 277 to 304, and in the annual report of the curator the collection is spoken of as one of the most important additions of the year. After Mr. Blake's return from South America he took charge of copper mines at San Fernando, Cuba, and he explored the Isle Royale* region at Lake Superior. In his office practice he was liberal in giving his professional brethren the benefit of his ideas, regarding that as his contribution to the advancement of science. He made suggestions to Babbitt about the alloy suitable for bearings, and to Goodyear about the vulcanization of India rubber.

About 1848 to 1864 Mr. Blake was in business as a consulting chemist and civil engineer in partnership with Franklin Darracott (who was a member of the Boston Society of Civil Engineers), with offices on State street and in Phœnix Building. Their business was largely gas engineering. They built the Worcester and

*The northeastern extremity of the island is called Blake's Point.

Lawrence gas works, which Mr. Blake organized. Mr. Blake was at one time president of five gas companies.

In the later part of his business career Mr. Blake became interested in street railways, and was president of the Metropolitan Railroad Company and of the Middlesex Railroad Company. He filled other important business and administrative positions.

He was elected a fellow of the American Academy of Arts and Sciences May 30, 1843.

Mr. Blake was one of the founders of the Boston Society of Civil Engineers, being one of the five who met at the preliminary meeting of April 26, 1848, and one of the committee to draft a constitution May 8, 1848. He was the first Secretary of the Society, his term of office being from July 3, 1848, to March 6, 1849. On April 4, 1849, he submitted for examination a model of a water meter. He wrote one of the earliest papers discussed before the Society on the use of lead pipes as service pipes. He was one of a committee who reported August 5, 1850, on the explosion of a locomotive boiler. Their report was printed in the *Boston Courier* of August 9, 1850. After the revival of the Society Mr. Blake was, with others of the earlier members, made an honorary member June 20, 1877.

His dominant characteristics were his simple faith, his courage, his kindliness, his love of truth and his earnest desire not to fail in doing his part of the world's work.

In his last years he was a confirmed invalid, but his mind remained active. He continued to reside in Boston with his son, Dr. Clarence J. Blake. He died July 5, 1899, in his ninety-first year. Within the next four months occurred the deaths of two of the other gentlemen with whom he had been engaged a half century before in the formation of the Boston Society of Civil Engineers, William S. Whitwell and Samuel Nott.

FREDERICK BROOKS.
WM. B. FULLER.
Committee of the Boston Society of Civil Engineers.

Roswell H. St. John.

By A. Lincoln Hyde, John W. Langley and A. H. Porter, a Committee of the Civil Engineers' Club of Cleveland.

Roswell H. St. John, a member of the Civil Engineers' Club of Cleveland, was born in Cincinnati, Ohio, in 1832. He was of English lineage, his ancestors having come to this country from England in 1700. While he was yet a boy his parents removed to Springfield, Ohio, where, after receiving a common school education, he learned the trade of watchmaker and jeweler. He was engaged later in this line of business in Bellefontaine, Ohio, and perfected various inventions applicable to his trade. Among these was the St. John universal chuck lathe, said to be the first foot lathe used by watchmakers.

At the breaking out of the war of the Rebellion, he was appointed member of the county military committee and later provost marshal for the fourth military district of Ohio. He continued in the latter position until the close of the war.

On the return of peace he again devoted himself to business, and became interested in sewing machines both as an inventor and manufacturer. He developed a number of valuable improvements in this line, and in 1877 the St. John sewing machine was perfected and a large factory for its manufacture was established at Springfield, Ohio.

Mr. St. John took up his residence in Cleveland in 1885, and shortly after commenced work on the typobar. He conceived the idea of making a type bar by what he termed the cold process, the bar being produced by pressing a solid body and a strip of flowing type metal together against assembled matrices, no heat being used. The operation forces a strip upon a tongue on the body of the bar and at the same time imprints the assembled characters upon the strip. The development of the process and a machine for its execution wholly engrossed Mr. St. John's time for the past ten years.

Mr. St. John took his completed machine to New York late in the year 1898, and the St. John Typobar Company, capitalized at $8,000,000, was organized by New York and Washington capitalists. A factory for the manufacture of his invention is to be built in Cleveland. Mr. St. John had just returned to the city and was engaged in the purchase of machinery for the plant a day or two before his death. He died of heart failure at his residence on Case avenue, July 27, 1900, after an illness of but a few hours.

Mr. St. John married in 1852, and his widow and four children, two sons and two daughters, survive him.

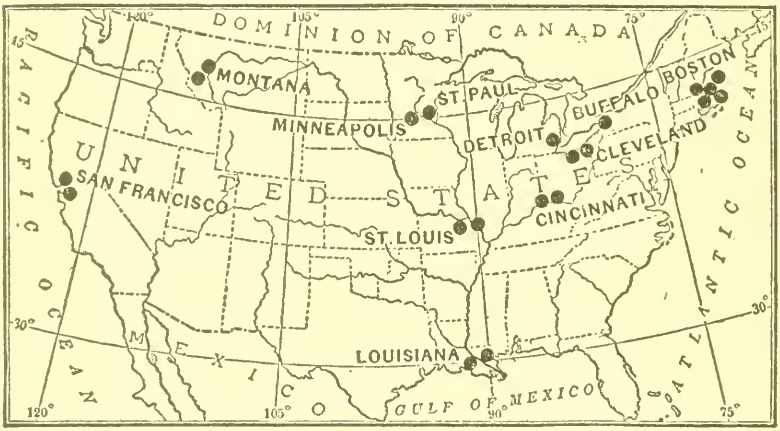
Mr. St. John became a member of the Civil Engineers' Club of Cleveland in 1890, and although not a regular attendant at the meetings, he ever had the best interests of the Club at heart, and was highly esteemed and respected by those members who came in contact with him.

It is fitting that the following resolutions to his memory be adopted:

WHEREAS, Roswell H. St. John, member of the Civil Engineers' Club of Cleveland, died on Friday, July 27, 1900; therefore, be it

Resolved, That this death has removed from us one of our esteemed members, and that the sincere sympathy of the Club be extended to the members of his family.

A. LINCOLN HYDE,
JOHN W. LANGLEY,
A. H. PORTER,
Committee of the Civil Engineers' Club of Cleveland.


DOMINION OF CANADA
MONTANA
ST PAUL
MINNEAPOLIS
BOSTON
BUFFALO
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
CINCINNATI
ST. LOUIS
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
LOUISIANA
GULF OF MEXICO
120°
105°
90°
75°
45°
30°

Association of Engineering Societies.

Vol. XXV. JULY, 1900. No. 1.

PROCEEDINGS.

Louisiana Engineering Society.

A special meeting of the Society was held on May 7, 1900, at 8.15 P.M., to take action upon the act prepared by the Legislative Committee for the Society to indorse.

President Malochee called the meeting to order with the following members present: Messrs. Coleman, Bell, Hardee, Ordway, Benson, Wright, Theard, Tutwiler, Flannagan, Jno. Richardson, Black and Lombard. There were also present, by invitation, two guests. Mr. William Woodward was the only architect who responded to the numerous invitations sent out to the architects of the city.

The Legislative Committee submitted a written report, placing before the Society a neatly and conveniently printed act regulating the practice of engineering and surveying, and asking the Society's indorsement of same. By motion, duly seconded, the report of the committee was received, and the act taken up section by section, with the understanding that any voting done by the members of the Society upon the amending or the approving of the act or any part of same was not to be considered binding upon such members to support the act, or *any* act looking for legislation, but was merely for the purpose of determining the proper and best form of act, in case it was subsequently determined to seek legislation, either with the indorsement of the Society or without it. After full discussion a few amendments were made.

A motion was then put and carried whereby the adoption of the act as amended, and in its entirety, was postponed until next Monday, May 14, when the regular monthly meeting will occur, in order to give the architects another chance to join us in a conference before we finally adopt any act. In the same motion the Secretary was instructed to issue notices of said conference for May 14, inviting all the practicing architects and others interested in the proposed legislation to attend not only the conference, but the meeting of the Society as well, and offering them the use of the floor during the conference.

Professor Woodward's views were listened to with interest. By a unanimous vote of those present the meeting hour next Monday was changed to 7.30 instead of 8 o'clock as usual.

The meeting then adjourned at 11 P.M.

Gervais Lombard, *Secretary.*

On May 14, 1900, the regular monthly meeting of the Society was called to order at 8 P.M. by President Malochee, with twenty-four members and ten guests present.

The minutes of the last regular monthly meeting and of the two special meetings of the Society held since were read and approved.

The minutes of the last regular monthly meeting of the Board of Direction were read for the information of the Society.

There was no report from the House Committee, but the Chairman of the Library Committee reported that the back numbers of the journals and magazines, which were ordered bound, were ready for the shelves and would be sent here in a day or two.

The Chair announced that he was sorry to inform those present that Mr. James C. Haugh, who was to have read a paper at this meeting upon "Pile Driving and Creosoting," was absent from the city, and that there would be no paper read to-night. Hereupon a motion was put and carried that Mr. Haugh be requested to read his paper at the next regular meeting of the Society, and that Mr. Hardee be asked to come prepared to read his paper, in case Mr. Haugh should be out of the city on that occasion.

The resolution introduced by Mr. Theard at the last meeting, and a notice of which was sent out with the notices of this meeting, was taken up for consideration, and after long discussion was voted upon and lost.

The amendment to the Constitution proposed by Mr. Theard, notice of which had been given in the same manner, was taken up, and by motion approved by the Society, and laid over till next meeting for second and final vote. It is as follows:

"To Article II, Section 3, of the Constitution, add: 'He can be transferred to the grade of member when qualified to become so under Section 2 of this article.' "

At this point a motion was put and carried that the Society take a recess for half an hour in order to hold a conference with a number of the leading architects who had been invited to attend and give their views upon the proposed legislation.

At the end of the recess the meeting was again called to order, and a motion was passed thanking the architects who had attended the conference, in response to our invitation, and inviting them to visit our rooms occasionally.

By resolution, action upon the act which was proposed was deferred.

Meeting adjourned at 10 P.M.

Gervais Lombard, *Secretary*.

June 4, 1900.—A special meeting of the Society was called to order at 8.20 P.M. by President Malochee, with the following members present: Messrs. Malochee, Theard, Ordway, Lawes, Llewellyn, Tutwiler, Zander, Wright, Coleman, Hyatt, Benson and Armstrong.

In the absence of Secretary Lombard, Mr. Coleman acted as Secretary. The object of the meeting was to receive and act upon the report of the Conference Committee on Legislation. Mr. Coleman was Chairman of the committee, and reported that it would be impossible to draft an act on which both the engineers and the architects would agree, and that the architects had volunteered, in consideration of the elimination by this Society of all reference to architects and architecture, not to go before the Legislature until the next session. The committee therefore recommended that their proposition be

accepted. Mr. Wright moved that the report be received, and its recommendation be adopted. Seconded by Mr. Hyatt, and unanimously carried.

The act was then carefully gone over and amended so as to leave out any reference to the architects or architecture, and also to change the length of time an engineer or surveyor must have practiced before the passage of the act, from *three* to *one* year, in order to be exempt from examination by proposed Board of Examiners. By motion duly seconded, the act as amended was indorsed by the Society, and laid over till the next meeting of the Society for the second and final indorsement. Adjourned.

GERVAIS LOMBARD, *Secretary.*

THE regular monthly meeting of the Society was called to order on Monday, June 11, 1900, at 8.15 P.M., by President Malochee, with seventeen members and one guest present.

The minutes of the last regular monthly meeting, and of the special meeting of the Society on June 4, were read and approved. The minutes of the special meeting of the Board of Direction on May 30, and of its regular monthly meeting on June 9, were read for the information of the Society.

The reports of the Secretary and of the Treasurer were read and approved. The Chairman of the Library Committee reported verbally that the back numbers of journals, magazines, etc., had arrived from the binder, neatly bound in convenient volumes, which are now in place in the bookcases, and that the committee had decided to index the volumes, and adopt certain rules allowing the members to take bound volumes home for short periods. The committee also announced the donation by Mr. F. T. Llewellyn of three years' back numbers of the *Engineering News.* By motion, which was duly seconded and carried, the report of the Library Committee was received, and a vote of thanks extended to Mr. Llewellyn for his generous donation.

By motion the Board of Direction was instructed to look into the matter of giving an outing, and to report upon it at the next meeting of the Society. The action of the Board of Direction in replying to the Committee of the Engineers' Society of Western New York, stating that our Society favored a Congress of Engineers with an exhibit at the Pan-American Exposition to be held in Buffalo, N. Y., in 1901, was ratified and approved by the Society.

By motion the usual order of business was suspended, and instead of the technical exercises commencing within a half hour after convening, they were deferred until the other business of the meeting was transacted.

By motion, duly seconded and carried, the following change in the Constitution, which was submitted by Mr. Theard and favorably voted upon for the first time at the last meeting of the Society, was favorably voted upon for the second and final time:

"To Article II, Section 3, add: 'He can be transferred to the grade of member when qualified to become so under Section 2 of this article.'"

Mr. Coleman moved that the Society indorse for the second and final time the proposed act regulating the practice of engineering and surveying, which was amended and favorably voted upon at the last meeting of the Society. Seconded by Mr. Theard and unanimously carried.

It was moved and carried that the act thus indorsed be referred back to the Legislative Committee with full power to urge its adoption by the Louisiana State Legislature, now in session, but with the understanding that

no expense be incurred without first obtaining the sanction of the Board of Direction. By motion, however, the Society authorized the committee to reprint the act as amended, at the expense of the Society, provided said committee deemed it necessary to do so.

President Malochee was authorized to answer Mr. Toledano's letter, and to assure the architects that we would not try to include them in our act this session, and in return for their assistance this session we would assist them, as far as possible, when they presented their act at the next session of the Legislature.

Mr. Theard notified the Society in writing of his intention to bring up the following proposed change to the Constitution, to be voted upon at the next meeting of the Society:

"Article II, Section I. The members of this Society shall be designated as members, associate members and junior members. Members alone shall have the right to hold office."

"Article VIII. All the rights of the Society shall be common to all the grades of membership except that of holding office, which shall be confined to members."

By motion it was decided to take a recess until such time as Captain Hardee would be able to read his paper, as he was unavoidably absent.

GERVAIS LOMBARD, *Secretary.*

THE regular monthly meeting of the Society was called to order by President Malochee on Monday, July 9, 1900, at 8.10 P.M., with eighteen members and one guest present. In the absence of Secretary Lombard, Mr. J. F. Coleman acted as Secretary.

The minutes of the last meeting of the Society were read and approved. The minutes of the regular meeting of the Board of Direction were also read for the information of the Society.

Chairman Theard, of the House Committee, stated that before he went any further with his investigations in regard to suitable quarters for the Society, when our present lease expired, he would like to have some suggestions from the members of the Society.

The report of the Library Committee, which had been submitted to the Board of Direction, was read in detail, and the action of the Board of Direction was called to the attention of the Society. The fines which were suggested in the rules governing the library were by motion eliminated, and the rules so amended were adopted by the Society. (See report of Library Committee on file.) Mr. Theard's report upon the reprinting of the charter and By-laws was referred to the Board of Direction, said board to report back.

Mr. Theard's proposed amendment to the Constitution which would give associate members the right to vote, but not to hold office, was taken up, and when voted upon was lost.

Mr. James C. Haugh was absent from the city, but his paper upon "Pile Driving and Creosoting in Connection with the Construction and Maintenance of the Trestle and Bridge Built by the N. E. R. R. Co. across Lake Pontchartrain" was read by the Secretary. By motion a vote of thanks was extended to Mr. Haugh, and discussion was postponed until the next meeting, when it was hoped that Mr. Haugh would be present. Mr. F. T. Llewellyn then spoke interestingly of his recent trip to Mexico. He was given a vote of thanks by the Society.

Meeting adjourned at 10.10 P.M. GERVAIS LOMBARD, *Secretary.*

Engineers' Club of St. Louis.

510TH MEETING, JUNE 13, 1900.—The meeting was called to order at 8.30 P.M. As neither President nor Vice-President was present, Mr. Edw. Flad was chosen to preside. Twelve members and four visitors were present. The minutes of the 509th meeting were read and approved.

The first paper of the evening was presented by Mr. Nils Johnson, on the "Duty Tests of High-Service Pumping Engines No. 9 and No. 10, St. Louis Water Works." A detailed description was given of the method adopted for making the official duty tests of the two 15,000,000-gallon triple-expansion pumping engines designed and built by the Edw. P. Allis Company, of Milwaukee, for the St. Louis Water Works. The contract rating of the engines called for a duty of 135,000,000 foot pounds per 1000 pounds of dry steam on a running test of twenty-four hours. A forfeiture by the makers is provided for in case of failure of either engine to perform the specified duty, at the rate of $2000 per 1,000,000 foot pounds per 1000 pounds of steam. In case either engine exceeded the duty as per agreement, the maker was to be entitled to a bonus as reward for the superior efficiency of the engine, an amount to be in the ratio of $1000 for each 1,000,000 foot pounds in excess of 135,000,000. In the duty test of twenty-four hours' duration, each engine surpassed the contract rating by over 40,000,000 foot pounds, earning a total bonus of about $85,000 for the builders.

The average rate of dry steam per 1 horse power per hour was 10.7.

The results of the above tests indicate the highest efficiencies thus far obtained with large pumping engines. These engines are located at the Baden High-Service Pumping Station. They hold the distinction of being record breakers. A number of slides were shown illustrating the apparatus and general scheme adopted in the tests. A number of tables were also shown, giving results and data of the engines. The discussion was participated in by Messrs. Flad, Russell, Freeman and Bausch.

The second paper of the evening was on "Tests for Elastic Properties and Ultimate Strength of Concrete," by W. H. Henby. Some original laboratory investigations were made of the elastic properties and ultimate strength of stone and cinder concrete in compression and tension under various conditions. The results of a number of these tests were presented. The discussion was participated in by Messrs. Russell and Johnson.

The meeting adjourned to an adjoining room, where lunch was served.

F. E. BAUSCH, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., MAY 16, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President Alexis H. French in the chair. Sixty-five members and visitors present.

The record of the last meeting was read and approved.

Mr. William C. Ewing was elected a member of the Society.

The thanks of the Society were voted to Rear Admiral W. T. Sampson, to Mr. Frank O. Maxson and Mr. J. W. G. Walker, civil engineers U. S. N., and to Commanders John E. Pillsbury and J. G. Eaton, U. S. N., for courtesies extended to members of the Society on the occasion of the visit to the Navy Yard at Charlestown on the 16th inst.

The Secretary read a series of resolutions which had been received from the Canadian Society of Civil Engineers expressing their sincere appreciation of the hospitality shown to them on the occasion of their visit to Boston. The resolutions were beautifully engrossed on parchment in colors.

The President then introduced Prof. Louis Derr, of the Massachusetts Institute of Technology, who read a paper, entitled "Automobile Vehicles." The paper was very fully illustrated by lantern views.

In the discussion which followed the reading of the paper, Mr. Knight Neftel, of the New England Electric Vehicle Transportation Company, Mr. J. B. Blood, Mr. G. S. Curtis and Prof. Derr took part.

On motion of Mr. Hodgdon, the thanks of the Society were voted to Professor Derr for his interesting and instructive paper.

Adjourned. S. E. Tinkham, *Secretary.*

Boston, Mass., June 20, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.; President Alexis H. French in the chair. Forty-five members and visitors present.

The record of the last meeting was read and approved.

Mr. Andrew M. Lovis was elected a member of the Society.

The Secretary read a communication from a committee of the Engineers' Society of Western New York in relation to the Pan-American Exposition, to be held in Buffalo from May to November, 1901, suggesting that it would be a most favorable opportunity to gather an engineering exhibit, and for the holding of a joint engineering congress or for each Society to hold its annual convention in that city during the Exposition. It also asked for an expression of opinion of this Society upon the matter. On motion the matter was referred to the Board of Government with full powers.

The President announced the death of John C. Haskell, a member of the Society, which occurred on June 12, 1900. On motion the President was requested to appoint a committee to prepare a memoir. The President has named as this committee Messrs. I. K. Harris and E. F. Dwelley.

Mr. Morris Knowles gave a very interesting account of the filtration experiments made at Pittsburg. The description was fully illustrated by lantern views.

Adjourned. S. E. Tinkham, *Secretary.*

Civil Engineers' Club of Cleveland.

Regular Meeting, June 12, 1900.—Called to order at 8.15 p.m. by President Hopkinson. Present, twenty-one members and six visitors. Messrs. E. E. Boalt, F. C. Osborn and H. C. Thompson appointed Reception Committee *pro tem.* Messrs. E. B. Wight and C. A. Palmer appointed tellers to canvass ballots for John T. Bever, Charles H. Davis, Andrew W. Foote, Harold H. Hill, Edward Horner, J. Verne Stanford and Wm. A. Stinchcomb, who were elected to active membership.

The names of Charles A. Cadwell and William C. Clark were proposed for active membership.

Letter from the Engineering Society of Western New York was read, asking for a committee from this Club to assist in making plans for an engineering exhibit at Pan-American Exposition. Prof. C. H. Benjamin

moved a committee of three be appointed for the purpose. Seconded by Mr. E. E. Boalt and carried. Messrs. Augustus Mordecai, A. H. Porter and M. E. Rawson were appointed.

It was moved and carried that this Club, in company with the other technical clubs, have an outing, details to be left with the House Committee.

The paper of the evening, entitled "The Inidikil System, or a Decimal System of Weights and Measures for the English Speaking People," was read by Mr. A. Lincoln Hyde, member of the Club.

Discussed by Messrs. William H. Searles, C. O. Palmer, C. H. Benjamin, C. W. Hopkinson, A. Lincoln Hyde, E. E. Boalt, Ludwig Herman and F. C. Osborn.

Moved by Mr. Robert Hoffman, Mr. Ludwig Herman second, that the Club adjourn to the semi-monthly meeting June 26, to discuss the questions in the Question Box. Carried.

Adjourned at 10 P.M. to lunch served in Club rooms.

ARTHUR A. SKEELS, *Secretary.*

SEMI-MONTHLY MEETING called to order 8.15 P.M. of June 26; President Hopkinson in chair. Present, nine members and three visitors.

Mr. C. O. Palmer opened the discussion on the following questions from the Question Box:

1. In what respects do the trusts benefit the public; in what respects are they detrimental to the public; and do the benefits outweigh the detriments?

2. In what respects do the trusts benefit the workingman; in what respects are they detrimental to the workingman; and do the benefits outweigh the detriments?

Discussion followed by Messrs. C. W. Hopkinson, A. Lincoln Hyde, Ludwig Herman, Lucian Rust and A. A. Skeels.

Mr. Ludwig Herman moved a committee of two be appointed by the Chair to call upon our late President, Col. Jared A. Smith, and express the regret of the Club occasioned by his proposed removal from the city.

Seconded by Mr. A. Lincoln Hyde and carried.

The President appointed Messrs. Ludwig Herman and A. Lincoln Hyde.

Adjourned 10.15 P.M.

ARTHUR A. SKEELS, *Secretary.*

Association of Engineering Societies.

Vol. XXV. AUGUST, 1900. No. 2.

PROCEEDINGS.

Technical Society of the Pacific Coast.

San Francisco, Cal., August 3, 1900.—Regular meeting called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved.

Mr. W. W. Oates, architect, of Stockton, was elected to membership upon a count of ballot, and Mr. George Wright, architect, was proposed by G. W. Percy, A. Ballantyne and Otto von Geldern

Mr. E. A. Rix read a paper entitled "Compressed Air Pumping," which was discussed at length.

The thanks of the Society were voted the author for his very comprehensive paper, and for his contribution to the literature on this important subject.

Adjourned. Otto von Geldern, *Secretary*.

Association of Engineering Societies.

Vol. XXV. SEPTEMBER, 1900. No. 3.

PROCEEDINGS.

Engineers' Society of Western New York.

September 4, 1900.—Meeting called to order at 8.15 p.m. The following members present: Messrs. Tutton, Diehl, Meyer, Knighton, Norton, Babcock, Lufkin, Sikes, Bardol, Tresise, Morse, and two visitors.

In the absence of the President, Mr. Tutton called the meeting to order.

It was voted that the minutes of the last regular meeting be approved as printed and circulated.

The report of the Pan-American Committee was left until the President arrived.

Mr. Lufkin was called to the chair, as Mr. Tutton was to address the Society.

Mr. Tutton.—I am to address you to-night on the reconstruction of the Kinzua viaduct.

As this bridge may be discussed before the American Society of Civil Engineers by the designers, I can give you but a brief description of the new mode of erection, etc.

The Kinzua viaduct, as most of you are aware, is in McKean county, Pa., and crosses Kinzua Creek and the Kushequa Railroad on the Bradford Division of the Erie Railroad. It is about sixteen miles south of Bradford and three miles north of Mount Jewett, and near Mt. Alton. The B., R. and P. R. R. runs around the end of this ravine not many miles to the north, I should say about five or six miles.

The old viaduct tablet, built in the masonry at the west or Mount Jewett end, reads as follows:

General Thomas L. Kane, President.

Robert Harris, Vice-President.

Octave Chanute, Chief Engineer.

Charles Pugsley, Principal Assistant.

C. H. Keefer and William Seaman, Assistants.

Located and designed by O. W. Barnes and A. Bonzano.

Masonry built by John C. Noakes.

Iron work built by Phœnix Bridge Company.

I understand the bridge was built by the Phœnix Bridge Company under the specifications of the Erie Railroad as they existed at that time; that is, in 1882. The Phœnix columns used were 9 inches in diameter.

The erection of the iron work was started about April 12, 1882, and I am a little in doubt about the date of completion. One tells me it was September 27; another that it was completed in October; and another that it was sometime in November of the same year.

The viaduct, as built, consists of two end spans 62 feet each, 19 clear spans, 61 feet each; 20 tower spans, 38 feet 6 inches, making the total length 2053 feet; maximum height, 301 feet. The old girders were uniformly 6 feet deep.

This structure is being replaced by the Elmira Bridge Company, with Grattan & Jennings as sub-contractors for erection.

The new lattice columns run about 2 by 3 feet. The new girders on the towers are 5 feet deep and on the clear spans 6 feet 7½ inches deep.

The work of tearing down the old structure commenced on May 20, 1900, when our first traveler was run out, and to-day we are working on the replacement of the last tower, and expect to complete the work this week, except a small amount of riveting.

The amount of iron in the old bridge was about 1500 tons, and in the new bridge approximately 3600, which will enable you to judge of their relative strength.

Both are single-track bridges.

The travelers and mode of construction were the result of studies of Mr. Gilman, superintendent of erection for Grattan & Jennings, and myself.

It will be noticed that the travelers are little more than a Howe truss bridge, without a bottom, whose width is 11 feet, ard whose load is all carried on the top, at which place, also, the bracing is made. It is also furnished with suspended sidewalks for the safety of the men employed.

(Mr. Tutton showed a number of photographs of the new mode of erection, together with tracing of the travelers, which were explained by him to the Society, as also was the unloading device, by means of which the iron was taken from the cars and piled where desired.)

The length of the travelers is 176 feet.

They are mounted on double trucks at each end, and after being moved they are held in position by being simply jacked up and held by blocks.

The design of this viaduct is quite different from previous practice, and may call forth criticism on the part of bridge engineers on account of its lack of wind bracing.

The Elmira Bridge Company designed the bridge; that is, I understand, it is their design, they having submitted several designs to Chief Engineer C. W. Buchholz for his approval. The towers are braced longitudinally; there is no transverse bracing other than what you might call portal bracing.

The masonry has all been repaired, and most of it was in good shape.

I was very glad the sidewalks were in place when I had occasion to go out on the bridge.

Mr. Knighton.—How is the spreading of the tower posts accomplished without the use of spreaders?

Mr. Tutton.—When the beams are suspended it takes but little force to pull them to position, the rope being flexible and long enough to act like a pendulum. We designed and built an apparatus that we called a spreader, but found we had no occasion to use it.

The batter is 2 inches per foot.

The old structure was theoretically safe under the specifications in use at that time, but the weights of cars and engines have changed materially since.

Under the present conditions it would not be considered safe, although I do not mean to imply that the structure would now be unsafe except for the fact of the great increase in trainloads and engine weights.

We use compresssed air for the riveting. We are not doing the painting.

It was moved and seconded that a vote of thanks of the Society be extended to Mr. Tutton for his very interesting and instructive address. Carried unanimously.

Mr. Diehl.—Mr. President, Mr. Bardol, who was appointed a member of the Pan-American Committee in place of Mr. Lufkin, who resigned, was present at the meeting this morning of the Committee of the American Society of Civil Engineers and the Pan-American Committee of this Society, and I would ask that Mr. Bardol be called upon to tell us about the meeting.

Mr. Bardol.—We did not do very much. At 10 o'clock Mr. Haven telephoned, asking if I could attend the meeting. When I got there I found Major Symons and Mr. Haven, of this Society, and Mr. Noble, Chairman, Professor Ricketts, Mr. Cartright, Mr. Seamans and Mr. Wisner, the Committee of the American Society of Civil Engineers on the Pan-American Exposition.

Major Symons acted as our spokesman, and explained his views. He stated that he would like to have the co-operation of the American Society and other societies to bring about an engineering exhibit next year. The question of expense was taken up, and the gentlemen from the American Society asked where the necessary money was coming from. Major Symons stated that he had talked with Mr. Buchanan, and thought it would not be difficult to get sufficient money to see us through. The gentlemen of the American Society agreed with the suggestion of Mr. Buchanan that it was necessary to obtain a competent manager to take charge of the exhibit, and to get other societies to co-operate with us.

We took the big automobile and inspected the Pan-American grounds, etc. The gentlemen were very much impressed with the size of the undertaking, and they came back and held a meeting in the afternoon.

Mr. Diehl.—Was anything said about a congress?

Mr. Bardol.—They spoke about that, but thought it was not practical. It is intended simply to have an engineering exhibit with some prominent engineer in charge.

They spoke about establishing headquarters to entertain visiting engineers.

Mr. Lufkin.—Was anything said about getting engineering societies to hold their conventions here next year?

Mr. Bardol.—No, sir. Something was said about having an American Society Day, but nothing was said about a convention.

The American Society of Municipal Improvements, which is composed largely of engineers of cities, is to hold its convention at Niagara Falls next year. This will arouse some interest.

Mr. Meyer.—What is meant by an engineering exhibit?

Mr. Bardol.—To have drawings and models. They have models of American cities at the Paris Exposition. Boston and New York furnished very elaborate exhibits.

Major Wheeler also attended the meeting, and went out to the grounds with us. He was asked how much space could be obtained, and he said he thought 40 x 100 feet would be large. Unfortunately Mr. Buchanan is out of town, so nothing official was done, but it is certain the Pan-American

Company would do something toward defraying the expense. The gentlemen from the American Society did not think the Society should be called upon to pay any of the expense.

Mr. Tresise.—An article in *Engineering News* a couple of weeks ago stated that an informal ballot was taken by the American Society in London, for the place of their convention for 1901, and that Buffalo received the greatest number of votes.

Mr. Diehl.—At this meeting we were to have several reports of committees, and the President had arranged to have the printed copies of the new Constitution ready at this meeting. Mr. Haven was taken ill to-day, and, in view of this fact, the reports will have to be delayed until the next meeting.

Meeting adjourned at 9 p.m. G. C. Diehl, *Secretary.*

Louisiana Engineering Society.

The regular monthly meeting of the Society was called to order on Monday, August 13, 1900, at 8 p.m., by President Malochee, with seventeen members and one guest present.

The minutes of the last meeting of the Society were read and approved, and the minutes of the meetings of the Board of Direction held on July 14, July 28 and August 11 were read for the information of the Society.

The monthly statements of the Secretary and of the Treasurer were read and approved.

The House Committee submitted a written report showing progress, and asking to be authorized to continue investigations with full power to act. The report was received and its recommendations approved.

The Legislative Committee made a written report explaining why the proposed "act regulating the practice of engineering and surveying" had failed to pass the State Legislature. The report was received.

The Committee upon Revision of the City Building Laws made a verbal report of progress. Received.

Mr. Theard made a verbal report of progress upon the preparation of the Charter and By-laws for reprint. Received.

The recommendation of the Board of Direction in regard to the Society giving an "outing" to Avery's Salt Mines in the latter part of September or early part of October was approved.

At this point the President announced that the half hour of routine business must now be followed by the technical exercises, after which the routine business could be resumed.

Mr. James C. Haugh's paper upon "Pile-Driving and Creosoting," which had been read at the last meeting of the Society, was taken up for discussion. Pile-driving was a familiar subject to most of those present, and a long and unusually interesting discussion followed.

Mr. W. B. Wright had, at the request of the President, prepared a statement of his experience with pile-driving, and the paper he read was quite interesting. During the discussion Mr. Hazlehurst gave his experience with pile-driving in Algiers for the stand pipe of the Algiers Water Works Company, together with some useful formulas for obtaining the bearing power of piles in alluvial soil.

Major Harrod gave some useful information in regard to the foundations of the Custom House Building, together with statistics of its subsequent settlement.

New business was taken up and a motion was passed authorizing the reprint of the Charter and By-laws provided it did not cost more than $32.

The following resolution was put and carried:

Resolved, That the Louisiana Engineering Society does hereby extend to the Hon. Loys Charbonnet its hearty thanks for his assistance, and further tender of assistance, in the matter of the proposed act to regulate the practice of engineering in the State of Louisiana; further

Resolved, That the Secretary be instructed to transmit a copy of these resolutions to the Hon. Loys Charbonnet.

A motion was passed authorizing a committee of five members to be appointed by the President as an "Arrangement Committee" for the proposed "outing." President Malochee later appointed the following members to the committee: Messrs. F. M. Keer, Chairman; James C. Haugh, Jules Godchaux, J. J. Frawley and Ben. Andrews, Jr.

The meeting adjourned at 10.15 P.M.

GERVAIS LOMBARD, *Secretary*.

NEW ORLEANS, SEPTEMBER 20, 1900.—The regular meeting of the Society was called to order by President Malochee, at 8 P.M. on Monday, September 10, with eighteen members and one guest present.

The minutes of the last meeting of the Society were read and approved, and the minutes of the Board of Direction meetings held on August 18, August 30 and September 8 were read for the information of the Society.

It was moved and carried that the report of the Board of Direction be approved.

Chairman Kerr, of the Committee of Arrangements for the "outing," made a verbal report to the effect that steps had been taken looking toward the necessary arrangements, investigations, etc. So far no satisfactory arrangement had been made with the S. P. R. R. Co., but the committee was still in communication with the said railroad company, and expected to hear from them shortly. Basing the cost of the train and transportation upon the figures obtained about this time last year,—that is $350,—the committee estimates that with three hundred guests the total cost will amount to about $650, and the committee therefore recommends that the tickets be sold to the members of the Society at $1.50 each. This would leave a balance of about $200 to be met by the Society. The committee further recommended that, in order to properly boom the "outing" and make it a success, President Malochee be authorized to appoint, as soon as possible, several committees as follows: A Committee on Finance, a Committee on Refreshments, a Press Committee and a Train Committee. He stated that the above estimate included a substantial meal and light refreshments. By motion, the report was received and its recommendations approved, and the Arrangement Committee, together with the Board of Direction, was given full power to act, it being understood that care be exercised, as the matter was one which required careful handling.

At this point President Malochee was excused on account of a business engagement, and Vice-President Theard assumed the chairmanship

As Messrs. Hardee, Bell and Brow were all three absent, the discussion upon the New Orleans building laws was deferred.

The Chair announced that at our next meeting Mr. W. M. White would read a paper upon "Water Measurement of a Centrifugal Pump Test at Jourdan Avenue Drainage Station."

The Secretary was instructed to write to Mr. Klorer and request him to give his consent to being transferred to full membership, as he was eligible.

Meeting adjourned at 8.50 P.M.

GERVAIS LOMBARD, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., SEPTEMBER 19, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Alexis H. French in the chair; sixty-six members and visitors present.

The record of the last meeting was read and approved.

Mr. Charles C. Whittier was elected a member of the Society.

The thanks of the Society were voted to the Fore River Engine Works for courtesies extended on the occasion of the visit to its works on July 18, 1900; also to the New Bedford Water Board for courtesies extended on the occasion of the visit to the pumping station and reservoir of the New Bedford Water Works, on August 22, 1900. The thanks of the Society were also voted to the Rockport Granite Company, to Cape Ann Granite Company and to the Pigeon Hill Granite Company for courtesies extended to-day while visiting the granite quarries of these companies at Cape Ann.

The President announced the death of Moses W. Oliver, one of the oldest members of the Society, which occurred on September 8, 1900, and by vote of the Society the President was requested to appoint a committee to prepare a memoir. The committee appointed consists of Messrs. R. A. Hale and A. D. Marble.

The literary exercises of the evening were opened by Mr. Henry Manley with an account of the annual convention of the American Society of Civil Engineers held at London in July last. Mr. Edward Sawyer followed, giving some of the impressions left in his mind from a trip abroad the past summer. Mr. F. W. Hodgdon gave a very interesting description of some of the docks in England visited by him, and Mr. H. D. Woods spoke of some special features of interest at the Paris Exposition. Mr. Desmond FitzGerald concluded the exercises with some remarks on places visited by him during the summer.

Adjourned. S. E. TINKHAM, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, SEPTEMBER 7, 1900.—Called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved. A communication was read from the editor of the *Mining and Scientific Press,* requesting that the Society permit him to publish Mr. Dana Harmon's paper on "Stamp Milling," to be read this evening. The Secretary was instructed

to communicate with the editor, stating that there would be no objection to the publication of the paper after its appearance in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and that he would be notified in due time.

Mr. George A. Wright, an architect, was elected to membership by ballot. Mr. Dana Harmon read a paper entitled "Stamp Milling of Free Gold Ores," which was discussed.

After expressing the thanks of the Society to Mr. Harmon for the valuable contribution to the Society's transactions the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Association of Engineering Societies.

Vol. XXV. OCTOBER, 1900. No. 4.

PROCEEDINGS.

Engineers' Society of Western New York.

Regular Meeting, October 2, 1900, at 8.15 p.m.—Mr. Haven, President, in the chair.

The following members were present: Messrs. Haven, Diehl, Sikes, March, Knighton, Wilson, Cornell, Whitford, Buttolph, Kielland, Powell, Fell, Bassett and Norton.

The minutes of the last regular meeting were approved as printed.

The Executive Board reported that at the meeting of July 16 they found that the ballots were almost unanimously in favor of the proposed amendments to the Constitution and By-laws, and that they were declared adopted; also that a majority of the votes for regular meeting night were for Tuesday; also that the President was ordered to contract for printing 500 copies of Constitution and By-laws, as amended, which he has done.

The Treasurer reported that there was $30.88 in the treasury, and that he had in hand bills amounting to $49 awaiting payment.

The Secretary reported that there were twelve members who had not paid their dues for the current year.

The application for membership of Mr. Alonzo H. Watson was received. The President said that it had been approved by the Executive Board. The application was ordered submitted to a letter ballot.

The President reported that the Society had elected as members Mr. George Frederick Morse and Mr. Charles Henry Davis, and as associate Dr. Truman J. Martin.

The President called for a report of the Special Committee on Membership.

Mr. Buttolph, one of the committee, said that the Chairman of that committee had never called a meeting, therefore he did not know that anything had been done. The President said that he supposed that the object of committees of more than one person was that every member would do something and not leave everything to the person first named.

After some talk Mr. Buttolph moved that that committee be discharged and another of five members be appointed. Seconded by Mr. March, and so voted.

The President appointed Messrs. Buttolph (Chairman), Sikes, Cornell, Knighton and Wilson a committee to take immediate measures to increase our membership.

The Executive Board was authorized to have printed 500 blank applications for membership and other forms to conform to amended Constitution and By-laws.

The Librarian made a report on various things connected with the library, and after a full discussion it was unanimously voted that "When there is money enough available in the treasury, the Librarian shall be authorized to procure the *Engineering Index* for the years 1884 to 1899."

The Committee on Pan-American Engineering Exhibit reported informally that they were in correspondence with several gentlemen with a view of recommending one or more of them to the Director-General of the Pan-American Exposition Company as suitable persons to take charge of the matter.

The President was directed to appoint a committee of three on the program for the annual meeting, and he appointed Messrs. Wilson, Cornell and Speyer. (Mr. Wilson declined to act, and the President appointed Mr. Geo. M. Busch.) This committee is ordered to report progress at the November meeting.

The President read the papers in the "Topic Box" and requested members to talk on any of them.

Mr. March said, in reply to the President, that he would at the annual meeting talk on paving brick tests.

Meeting adjourned at 9.30 P.M. G. C. DIEHL, *Secretary*.

Technical Society of the Pacific Coast.

REGULAR MEETING, October 5, 1900.—Called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved.

Mr. Geo. W. Dickie addressed the Society, and related informally the experiences and observations of his recent journey to Europe, where he attended the meetings of the American Society of Mechanical Engineers and the American Society of Civil Engineers, in London, and visited the Paris Exposition.

Adjourned.

OTTO VON GELDERN, *Secretary*.

Louisiana Engineering Society.

PRESIDENT MALOCHEE called the meeting to order on Monday, October 8, at 8 P.M., with twenty-three members and two guests present.

The minutes of the last regular meeting of the Society were read and approved. The minutes of the regular meeting of the Board of Direction, held on October 6, were read for the information of the Society.

The reports of the Secretary and of the Treasurer were read and approved. They showed a balance in bank to date of $406.02.

The Chairman of the Library Committee reported verbally that twelve more volumes of back numbers had arrived from the bookbinder, and that the pamphlets from the U. S. Geological Survey, for which he had written, had also arrived. The record book was reported on the shelf,

and any member desiring to carry books home could now do so by receipting for them in the record book.

The Chairman of the Outing Committee, Mr. Kerr, made a verbal report to the effect that all arrangements for the outing to Avery Salt Mines on Saturday next had been satisfactorily completed, and that the outing was already an assured success. He was glad to report that the total cost was to be within the amount estimated at the last meeting,—namely, $650. This report was supplemented by that of Chairman S. F. Lewis, of the Finance Committee, who stated that so far the tickets sold amounted to about $350. Mr. DeBuys, the Chairman of the Refreshment Committee, stated that he had contracted for all the refreshments needed, and that, besides light refreshments served on the train going and coming, a substantial noonday meal would be served in a new assembly hall at the mines.

President Malochee announced that Mr. A. M. Lockett would read a paper at the November meeting upon the subject of "Condensers."

The Secretary was instructed to send each member of the Society a copy of the Constitution and By-laws, and to also send one to each of the Societies forming the Association of Engineering Societies.

Under the head of Technical Exercises Mr. W. M. White read a paper upon "Water Measurement of a Centrifugal Pump Test at Jourdan Avenue Drainage Station." Great interest was manifested, and after the discussion a vote of thanks was passed expressing to Mr. White the sincere appreciation the Society felt for his most interesting paper. Mr. J. F. Coleman was announced as Chairman of the Train Committee for the outing, said committee to consist of twenty-four members.

The meeting adjourned at 9.45 P.M.

GERVAIS LOMBARD, *Secretary*.

Montana Society of Engineers.

REGULAR MEETING, October 13, 1900.—Meeting was called to order by President Blackford at 8.30 P.M., with the following members present: Harper, Christian, R. R. Vail, Moore, Sickles, Macdonald, Page, Dunshee and McArthur, and two visitors, Messrs. North and Ingersoll. The minutes of the last meeting were read and approved.

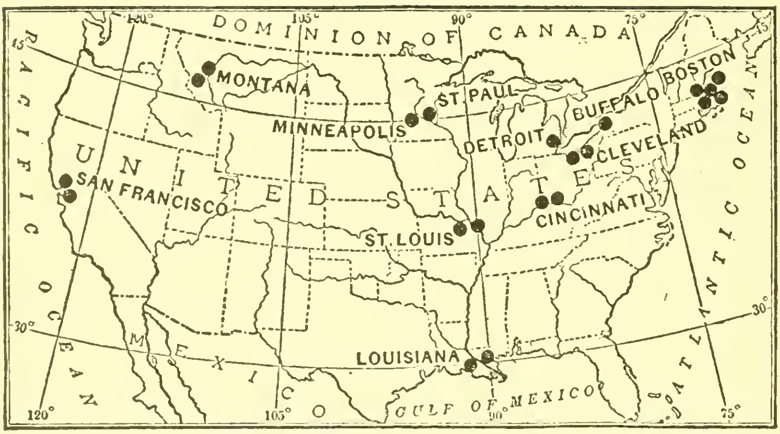
The application of Mr. Charles H. Davis was read and, after discussion, the By-law of the Society with reference to the indorsement of the application of at least two members was waived by unanimous consent and the Secretary instructed to send out the usual letter ballot. The Secretary was instructed to purchase a blackboard for the Society.

This completing the business before the meeting, the President introduced Mr. E. C. Sickles, of Anaconda, who read a paper on "The Compression of Air." The speaker took up the single-phase and double-phase type of air compressors and discussed quite fully the relative advantages and efficiency of each, illustrating his remarks by many sketches and drawings.

The paper brought out an interesting discussion from the members, in which Messrs. Blackford, Christian, Harper and Page took part.

Adjourned.

R. A. MCARTHUR, *Secretary*.



DOMINION OF CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
UNITED STATES
MEXICO
GULF OF MEXICO
MONTANA
ST. PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
120°
105°
90°
75°
45°
30°

Association of Engineering Societies.

Vol. XXV. NOVEMBER, 1900. No. 5.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., October 17, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Alexis H. French in the chair; ninety-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Charles H. Davis and Alfred T. Tomlinson were elected members of the Society.

Mr. Frederick Brooks, for himself and Mr. Wm. B. Fuller, a committee appointed to prepare a memoir of Mr. John H. Blake, submitted and read its report.

Mr. Robert S. Hale then read the first paper of the evening, entitled "A Successful Siphon."

In the absence of the author, the Secretary read a paper by Mr. William D. Bullock, entitled "Description of Experiments on Brick and Concrete Arches."

Mr. Frederic H. Fay read a paper describing some tests made by the Engineering Department of Boston on "The Strength of a Rapp Floor and of a Gustavino Arch Floor." The rest of the evening was devoted to accounts of several of the systems of concrete floor and arch construction, which were liberally illustrated by lantern views. Mr. William M. Bailey spoke of expanded metal in connection with concrete construction. Mr. M. C. Tuttle described the Ransome system of concrete work, and Mr. A. W. Woodman the Roebling system.

After passing votes of thanks to Messrs. Bailey, Tuttle and Woodman, the Society adjourned.

S. E. Tinkham, *Secretary*.

Boston, Mass., November 21, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M., President Alexis H. French in the chair; fifty-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Roy C. Aiken and Alfred M. Wyman were elected members of the Society.

The Secretary read a communication from the Chairman of the Board of Managers of the Association of Engineering Societies extending an invitation

to the members of this Society to discuss any of the papers published in the JOURNAL; discussions to be forwarded to the Secretary of the Association not later than three months from the date of publication of the number in which the paper appears. Authors of papers will be allowed to close the discussion, if desired, in a subsequent issue not over two months later.

On motion of Mr. Hodgdon, it was voted that the thanks of the Society be extended to the officers of the Boston Elevated Railway Company for courtesies extended at this afternoon's excursion.

Mr. William O. Webber read the paper of the evening, entitled "The Use of Water Powers by Direct Air Compression." The paper was illustrated by numerous lantern views. After a discussion in which Messrs. R. A. Hale, Blood, Coffin, Porter and Webber took part, the Society adjourned.

S. E. TINKHAM, *Secretary.*

Engineers' Club of St. Louis.

511TH MEETING, ST. LOUIS, SEPTEMBER 19, 1900.—The meeting was called to order at 8.20 P.M., President Chaplin in the chair; nineteen members and nine visitors were present. The minutes of the 510th meeting were read and approved. The report of the 295th meeting of the Executive Committee was read. The applications for membership of Charles Henry Davis, Hugo Frederick Urbaner, Charles H. Tucker and Duncan F. Cameron were presented to the Club.

The paper of the evening, on "The Electrical Features of the Paris Exposition," was presented by Prof. H. B. Shaw, of the State University of Columbia. Although Professor Shaw did not attend the exposition, he reviewed, in a most interesting manner, the important electrical features connected with the exposition, accounts of which appeared in various technical journals. A general description was given of the exposition grounds. The moving sidewalk, operated by two large motors, was compared with the one at the Chicago World's Fair. The motors were each 850 horse power, the largest ever built. The third-rail road and a number of foreign constructions of engines and generators were described.

The meeting adjourned to the neighboring room, where a light lunch was served.

F. E. BAUSCH, *Secretary.*

512TH MEETING, ST. LOUIS, OCTOBER 3, 1900.—The meeting was called to order at 8.15 P.M., with President Chaplin in the chair; thirty-seven members and six visitors were present. The minutes of the 511th meeting were read and approved. The minutes of the 296th meeting of the Executive Committee were read.

The names of Messrs. Charles H. Tucker, Charles Henry Davis, Hugo Frederick Urbaner and Duncan F. Cameron having been recommended by the Executive Committee, they were balloted for and declared duly elected members of the Club.

The Committee on Club Quarters made a report without recommendation. It was moved and seconded, and the motion carried, that the Executive Committee arrange for another evening at the Office Men's Club before making a final decision upon the offer proposed to the Engineers' Club.

Mr. J. A. Ockerson made a report upon his duties as delegate from this Club to the meetings of the Society of Civil Engineers of France.

The paper of the evening, on "The Paris Exposition of 1900," was presented by Mr. J. A. Ockerson. A general description was given of the grounds, buildings and distribution of exhibits, alluding also to the tramways of Paris and transportation facilities. A comparison was made between the Paris Exposition and the Chicago World's Fair, the essential difference between the two being the greatly scattered condition of the buildings and departments of the former as compared with the plan of concentration and architectural effect of the latter. Mr. Ockerson exhibited some excellent slides, and presented maps showing location of exhibits at the World's Fair.

The meeting adjourned to an adjoining room, where a light lunch was served. F. E. BAUSCH, *Secretary*.

513TH MEETING, ST. LOUIS, OCTOBER 17, 1900.—The meeting was called to order at 8.15 P.M., with President Chaplin in the chair; twenty-four members and four visitors were present. The minutes of the 512th meeting were read and approved. The minutes of the 297th meeting of the Executive Committee were read.

The application for membership of Gerard Swope having been recommended by the Executive Committee, he was balloted for and declared elected.

The paper of the evening was on "The Sewer System of St. Louis," presented by E. M. Hermann, Sewer Commissioner. The paper treated of the construction, maintenance, repairs, cleaning and general operation of the sewers of St. Louis. Mr. Hermann presented charts showing cross-sections of many of the larger sewers, the method of construction and materials used in the walls, etc. He also exhibited a collection of lantern slides giving views of the interiors of the sewers, showing peculiar construction in many places and the character of the breaks and fissures in the decaying walls of the old sewers that were caused by the giving way of walls undermined by the flow of sewage after the bottoms had been worn through. The subject was discussed by Messrs. Moore and Petzmann, and by Professors Van Ornum and Kinealy.

The meeting adjourned to the adjoining room, where lunch was served.

F. E. BAUSCH, *Secretary*.

Louisiana Engineering Society.

NEW ORLEANS, NOVEMBER 15, 1900.—The regular monthly meeting of the Society was called to order on Monday, November 12, 1900, at 8 P.M., by Vice-President Theard, with fourteen members and one guest present.

The minutes of the last meeting of the Society were read and approved. The minutes of the Board of Direction meeting, held on November 10, were read for the information of the Society. The reports of the Secretary and of the Treasurer were read and approved. They showed a balance on hand of $203.70.

Mr. Kerr, as Chairman of the Arrangement Committee for the "outing," submitted a final written report, which was received, and the committee relieved of further duty. The following resolutions were passed:

Resolved, That the thanks of the Louisiana Engineering Society are due and are hereby tendered the officials of the Southern Pacific Company for the elegant service, and the efficient, courteous train crew furnished for the "outing" to Avery's Island, on October 13, 1900.

Resolved, That the thanks of the Louisiana Engineering Society are due and are hereby tendered the Avery Island Rock Salt Mining Company for the courteous and generous reception accorded the Society on its outing on October 13, 1900, recognizing the extent to which the management incommoded itself and its officers and employes in furnishing the opportunity and means to descend into the mines and to inspect their magnificent plant, not to mention other personal courtesies during the course of a most enjoyable day.

WHEREAS, The outing to Avery's Island, given by the Louisiana Engineering Society, on October 13, 1900, has proved a complete success, affording to our members an interesting study of the resources of our State, and offering an agreeable recreation to our guests; and

WHEREAS, The success of the outing was conditional upon its proper management; be it

Resolved, That the thanks of the Louisiana Engineering Society are hereby tendered to the following gentlemen for the able and efficient manner in which they performed the duties assigned to them on that occasion: President H. J. Malochee; Chairman Kerr, of the Arrangement Committee; Chairman Lewis, of the Finance Committee; Chairman Perrilliat, of the Press Committee; Chairman DeBuys, of the Refreshment Committee; Chairman Coleman, of the Train Committee, and the several members of the respective committees.

The Secretary was ordered to spread the above resolutions upon the minutes, and to send copies to the proper parties.

A tabulated statement of the assets and the probable liabilities up to January 1, 1901, which had been prepared by the Secretary at the request of the Board of Direction, was read. It showed that the probable balance to the credit of the Society after all bills are paid will amount to about $435.

A motion was passed that the Society give a smoker similar to the one given last year. Said smoker to be given on the night of the December meeting, and not to cost more than $75.

The communication from Mr. James Ritchie relative to discussion of papers appearing in the JOURNAL was read, and a committee of three, with Mr. Tutwiler as Chairman, and Messrs. W. M. White and Zander, members, was appointed to go over the grounds and decide what the best method of procedure would be, and to report back to the Society.

Mr. A. M. Locket stated in a communication that his prolonged absence from the city would prevent him from reading his paper at this meeting, but that he would not fail to read it at the December meeting.

The meeting adjourned.

GERVAIS LOMBARD, *Secretary.*

Engineers' Club of Cincinnati.

118TH REGULAR MEETING, CINCINNATI, OHIO, OCTOBER 18, 1900.—Dinner was served at 6.30 P.M.

The regular meeting was called to order at 8 P.M.; President Punshon in the chair, and fifteen members present.

Minutes of the meeting of September 20 were read and approved.

On ballot being taken, Mr. Charles H. Davis, of New York city, was elected an active member.

The paper for the evening, by Col. Latham Anderson, on "Economy Attainable by the Use of the Hydraulic Giant in Making Extensive Cuts and

Fills in Clay or Gravel," was read by Mr. Elzner in the absence of the writer.

The paper comprised a discussion and description of various methods of excavating by hydraulics, with a special plea for the use of the hydraulic giant, with instances of work accomplished by it at comparatively small cost, concluding with a recommendation of this method for removing material from the hills west of Cincinnati for filling Mill Creek bottoms.

After some discussion of the subject and a vote of thanks to the writer of the paper the meeting adjourned.

J. F. Wilson, *Secretary.*

119th Regular Meeting, Cincinnati, Ohio, November 15, 1900.—Dinner was served at 6.25 p.m.

The regular meeting was called to order at 7.30 p.m.; with President Punshon in the chair and nineteen members present.

Minutes of the meeting of October 18 were read and approved.

Application for active membership, properly indorsed, was presented by James C. Hobart, secretary and manager the Triumph Electric and Ice Machine Company, of Cincinnati, Ohio.

The Secretary reported the death of Sherman E. Burke, which occurred accidentally at Dennison, Ohio, on October 17, while participating in an inspection trip over the lines of the Pennsylvania Railroad system, with which he was connected. On motion, the Chair appointed a committee, consisting of Messrs. James A. Lilly and J. A. Rabbe, to prepare a suitable resolution in respect to the deceased member.

The Secretary read a communication from Mr. Hugo Diemer, now a professor at the Michigan Agricultural College, in which he urged that the sentiments of the Club be expressed to the effect that the proposed establishment of a department of mechanical engineering at the University of Cincinnati be upon a basis on a par with the other scientific and classical departments. On motion, the same was laid on the table.

The paper for the evening, received from Mr. W. B. Ruggles, now Assistant Engineer of the Department of Western Cuba, entitled "Improvement of Matanzas Harbor," in which he described the various plans for the work, was read by Mr. L. E. Bogen. After the reading of the paper, Mr. Bogen exhibited a number of lantern slides from views illustrative of Cuban life and characteristic of that country, in which he was assisted by Mr. J. P. Horstman, who was assistant to Mr. Ruggles on the work, and who has recently returned from Cuba.

A vote of thanks was tendered Mr. Ruggles for his interesting paper, and to Messrs. Bogen and Horstman for the rendition of the same and the preparation, exhibition and description of the views.

On motion, adjourned.

J. F. Wilson, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, November 2, 1900.—Called to order at 8.30 p.m. by President Percy.

The minutes of the last regular meeting were read and approved.

The Secretary read a letter from Mr. Trautwine, of the Association of Engineering Societies, suggesting certain changes in the wording of

the paper on the subject of "Stamp Milling of Free Gold Ores." Upon motion, this matter was referred to the Board of Directors, with the instructions that the paper be submitted to the Committee on Publication for suitable revision.

A resolution was read embodying a memoir on the late member, W. G. Curtis, which was ordered spread upon the minutes and copies sent to the nearest relatives of the deceased. Also ordered published in the JOURNAL OF ENGINEERING SOCIETIES as customary, with a half-tone photograph of the late member.

The Secretary reported the death of Fred. W. Wood, of Los Angeles, and was instructed to communicate with some of the Society's members in that locality for the purpose of obtaining a memoir.

The President appointed a committee consisting of Messrs. E. F. Haas, J. G. H. Wolf and Otto von Geldern to assort the unbound JOURNALS on file in the library, so as to get a certain number of them bound, and to report the probable expense of such work.

Mr. G. Alexander Wright read a paper on the subject of "Arbitration: Its Place in Our Professional Practice," which was discussed by Mr. E. J. Molera and Mr. George W. Dickie.

Meeting adjourned. OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., NOVEMBER 5, 1900.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Present, ten members and six visitors; President Powell in the chair. Minutes of previous meeting read and approved.

A rather informal and indefinite verbal proposition from the Commercial Club, touching the appointment of committees by that body and our own to confer on the advisability of closer relations between the two, was referred to the government of the Society for more definite development. The resignation of Mr. H. N. Elmer was accepted. A general invitation by Mr. James Ritchie, Chairman of the Board of Managers A. E. S., to discuss the published papers of the Association, was read.

No action was taken on communications from the Technical Agency of Newton, Mass., and from Mr. T. W. Hurst.

The application for membership, submitted by the Examining Board, of Mr. Charles H. Davis, of New York, was referred to a committee to examine and report on at the next regular meeting.

Mr. Oliver Crosby read a paper on "The Manufacture of Steel Castings by the Tropenas Process." He made special reference to the plant of the American Hoist and Derricks Company, and exhibited some striking and curious specimens of the steel, together with drawings, tables, etc.

C. L. ANNAN, *Secretary.*

Association of Engineering Societies.

Vol. XXV. DECEMBER, 1900. No. 6.

PROCEEDINGS.

Engineers' Society of Western New York.

The annual meeting of the Society was held in the Society rooms, 975 Ellicott Square, at 4.30 and 8.30 P.M., Tuesday, December 4, 1900. There were present Messrs. Haven, Kielland, Knighton, Tutton, Buttolph, Norton, Whitford, Weston, Bardol, Roberts, Speyer, Babcock, Powell, Knapp and Fell. Mr. Knighton was appointed Secretary *pro tem.* The minutes of the last regular meeting were approved as printed.

Reports of the Executive Board, the Secretary, Treasurer, Librarian and Representative on the Board of Engineering Societies were received and referred to the Executive Board.

Messrs. Buttolph and Kielland were appointed tellers to canvass the vote cast for officers of the Society for the ensuing year. They reported that the vote was unanimous, and thereupon the President declared that the following persons were elected:

President—William A. Haven.

Vice-President—George H. Norton.

Directors—T. Guilford Smith, for one year; Louis H. Knapp, for three years.

Secretary—George C. Diehl.

Treasurer—George R. Sikes.

Librarian—John A. Knighton.

Applications for membership were read as follows: For members—Jasper S. Youngs, Henry Clark, Horace P. Chamberlain, Frank L. Bapst, Henry Bartlett Alverson, Charles L. Boardman, John T. Herron, John J. Clahan, Eugene C. Hanavan. For associates—Emmett W. Huntington, Charles Mosier, Louis Marburg.

The Secretary was ordered to send out letter ballots for the above-named candidates.

On motion of Mr. Norton, it was voted that the President appoint a committee of one to report at the next meeting on the question of our Society joining the American Section of the International Association for Testing Materials.

Mr. March was appointed as such committee.

Mr. Bardol made an informal report for the Pan-American Committee, and after considerable discussion it was voted that the Committee on Pan-American Affairs be discharged.

Mr. Bardol moved the adoption of the following resolution:

That the Secretary be directed to write a letter to Mr. Selim H. Peabody, Superintendent of Liberal Arts of the Pan-American Exposition Company, and intimate to him that this Society will appoint a committee to co-operate with him or the Exposition Company in the matter of an Engineering Exhibit, if they desire to have such an exhibit, and to call attention to what has been done; to report at the next meeting.

Seconded by Mr. Norton, and carried unanimously.

The President thanked the Society for his re-election as President, and said that the Constitution provided that the outgoing President should make a report and address, but that, as at the present time there did not seem to be an outgoing President, no address had been prepared. He spoke on the general condition of the Society, and what, in his opinion, should be done for its welfare. He also promised that before the next meeting he would write his address in a more formal way and deliver it to the Society.

The President then presented to the Society a "Description of a Compleat Enginier," copied from a book written by David Papillon, Gent., published in London, in 1645, chapter first of which book is headed "Of the True Character of a Compleat Enginier." This chapter was copied verbatim, and the President said he would have it properly framed and hung up in the rooms of the Society. The Society received the gift with a vote of thanks to the President.

Adjourned at 11.55 P.M.

JOHN A. KNIGHTON, *Secretary pro tem.*

REPORT OF THE SECRETARY.

BUFFALO, N. Y., December 1, 1900.

W. A. HAVEN, ESQ., PRESIDENT ENGINEERS' SOC. OF WESTERN NEW YORK, BUFFALO, N. Y.

Dear Sir,—In compliance with Article I, Section 3, of the By-laws, I submit the following report:

Members—January 1, 1900, there were thirty-two members whose dues were paid; thirty-one members whose dues were unpaid; total, sixty-three.

During the past year sixteen members have been indefinitely suspended for non-payment of dues; one member has resigned; one honorary member has been elected; twelve new members have been elected; one associate has been elected; seven applications for membership are on hand.

December 1, 1900, there were fifty-six members whose dues were paid; six members whose dues were unpaid; total, sixty-two.

DUES.

Total amount received from members from December 21, 1899, to December 1, 1900:

Entrance fees	$70.00	
Dues	497.50	
Key deposits	3.25	
		$570.75
Amount deposited with Treasurer		570.75

MEETINGS OF THE SOCIETY.

Nine meetings of the Society have been held since January 1, 1900, with an average attendance of eighteen.

Eleven meetings of the Executive Board have been held since December 16, 1899, with an average attendance of five.

On July 7, 1900, through the courtesy of Major Thomas W. Symons, U. S. A., the Society visited the United States Government Breakwater and work connected therewith.

Respectfully submitted,

G. C. Diehl, *Secretary.*

Condensed report of the Treasurer:

GENERAL FUND.

Cash on hand December 4, 1899	$138.89
Total received from Secretary, December 4, 1900	508.25
Interest on deposits, December 4, 1900	1.08
Total	$648.22

DISBURSEMENTS.

(See Classification)	$635.25
Cash on hand December 4, 1900	12.97
	$648.22

CLASSIFICATION OF EXPENDITURES, 1899-1900.

For expenses prior to annual meeting of 1899	$19.00
For expenses of annual meeting 1899	56.88
For monthly meetings, notices, reports and printing proceedings	90.75
For stationery, postage, etc	56.81
For amendments to Constitution and By-laws, typewriting and printing	42.75
For new bookcase	51.00
For additions to library	4.75
For membership in Association of Engineering Societies	94.75
For rent of 975 Ellicott Square	190.00
For miscellaneous expenses	28.56
Total	$635.25

PERMANENT FUND.

Cash on hand December 4, 1899	$80.00
Total received from Secretary, December 4, 1900	90.00
Interest on deposits	2.36
Total in Erie Co. Savings Bank	$172.36

Condensed by

W. A. Haven, *President.*

REPORT OF THE LIBRARIAN FOR THE YEAR 1900.

Buffalo, N. Y., December 4, 1900.

There has been expended on the library proper during the year the following amounts:

Bookcase	$51.00
Engineering Magazine	3.00
Engineer (London)	8.50
Water and Gas Review	.95
Cassier's Magazine	2.75
Topographical maps of New York State	2.00
Table of altitudes	.40
Engineering indexes	5.45
Temporary binding	4.75
Total	$78.80

Received for old bookcase $50, making a net expenditure of $28.80.

Additions to the library other than by purchase are as follows:

Exchanges	123	numbers.
Donations—Reports, etc.	433	"
Catalogues	23	"
Total	579	"
Periodicals, purchased as above	88	"
Total additions during year	667	"

This library is becoming more valuable each day for reference purposes, and in order that the material on hand may become properly available it is indispensable that a substantial appropriation be made each year for binding and for additional bookcases, as well as for current literature We need at present $50 for binding periodicals, etc., an ' an equal amount for bookcases.

An unfortunate feature in connection with our exchanges is that we have but little to offer Societies which publish their own proceedings, and are supplied from other sources with the Journal of the Association of Engineering Societies. As a result we have lost one valuable exchange during the past year.

The Society is especially indebted to Mr. John C. Trautwine, Jr., for a copy of "The Civil Engineer's Pocket Book," to Mr. George W. Rafter, for papers and reports, to Mr. Charles H. Tutton, for periodicals, and to Mr. Horatio A. Foster, for books and maps.

Respectfully submitted,

J. A. Knighton, *Librarian.*

Louisiana Engineering Society.

The regular meeting of the Louisiana Engineering Society was called to order on Monday, December 10, 1900, at 8 o'clock, by President Malochee, with thirty-eight members and fifty-five guests present.

The minutes of the last meeting of the Society were read and approved. The minutes of the meeting of the Board of Direction on December 8, 1900, were read for the information of the Society.

The monthly statements of the Secretary and of the Treasurer were read and approved. They showed a balance on hand of $326.17.

Chairman Kerr, of the Auditing Committee, made a verbal report, in which he called the attention of the members to the considerable sum it was necessary to pay to the collector, and requested the members to save

this amount to the Society by paying in their dues promptly upon receipt of the quarterly bills. Mr. Kerr's verbal report was received and approved.

The Library Committee submitted a written report (see Secretary's file) stating that ten more volumes of the back numbers of our periodicals had been sent to the binder, and that a handsome cypress case for the periodicals had been made and placed in the library. The committee also asked for authority to renew the subscriptions to all the periodicals now on our list, substituting the *Iron Age* for the *Army and Navy Journal*. The committee suggested that a monthly appropriation be made for the purpose of purchasing new books. The report was received and referred to the Board of Direction with full power to act.

Chairman Tutwiler, of the committee appointed to recommend the best method of discussing the papers appearing in the JOURNAL, in accordance with the request of Mr. James Ritchie, chairman of Board of Managers of the Association of Engineering Societies, made a written report recommending that, though Mr. Ritchie invited the individual members to discuss the papers, our President be authorized to select the paper to be discussed, and have the Secretary send the members, with the notices of the meeting, a notice of the selection of said paper for discussion, in order that those wishing to do so could prepare for the discussion. These discussions upon the floor to take place whenever the regular meetings of the Society were not entirely taken up with the Society's own transactions. After the discussion the President is to appoint some member present, who is specially fitted to do so, to take up the discussion and publish it in the JOURNAL. The committee further recommended that the Secretary be instructed to send a circular letter to the members informing them of Chairman Ritchie's invitation. The report was received, and its recommendations approved.

The nomination of officers for 1901 was declared in order, and a motion was passed that three tellers be appointed by the President to poll the votes. In accordance with the By-laws two names were balloted upon for nomination to each office. Messrs. DeBuys, Wright and A. Raymond were appointed tellers, and upon the first ballot they announced that Mr. Alfred F. Theard and Major Frank M. Kerr had been nominated for the Presidency. The balloting for Vice-President, etc., had commenced when a motion to adjourn was passed.

Then commenced a jolly smoker which lasted until midnight.

GERVAIS LOMBARD, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, DECEMBER 7, 1900.—Called to order at 8 [illegible] P. M. by President Percy.

The minutes of the last regular meeting were read and approved.

Mr. Wolf, member of the Committee on Binding Journals, reported what had been done in the matter of searching out the various periodicals and making a list of missing numbers. Further time was asked and granted.

The following committee was appointed by members present for the purpose of nominating a list of officers of the Society for the year 1901: C. E. Grunsky, J. H. Wallace, Hubert Vischer, Luther Wagoner and G. A. Wright.

The Secretary was instructed to notify these members of their appointment.

The following applications for membership were made:

For members—Harris D. Connick, civil engineer, of San Francisco, proposed by Luther Wagoner, Edw. F. Haas and Otto von Geldern; John J. Hollister, civil engineer, of Santa Barbara, Cal., proposed by Luther Wagoner, Edw. F. Haas and Otto von Geldern; Norman B. Livermore, civil engineer, Board of Public Works, San Francisco, proposed by Luther Wagoner, Edw. F. Haas and Otto von Geldern.

Mr. George W. Dickie read a paper on the subject of "The Need of Education of the Judgment in Dealing with Technical Matters," which was discussed at length.

Adjourned. Otto von Geldern, *Secretary.*

Death of President George W. Percy.

The President of the Technical Society of the Pacific Coast, Mr. G. W. Percy, died in Oakland, Cal., on December 14, 1900. His death, due to heart trouble, came as a sudden surprise to all, for he had been at his office on the day preceding his death, and had presided at a meeting of the Society a few days before the sad news came that the name of its genial President had to be stricken from the roll forever.

Funeral services were held on Sunday, the 16th, attended by the members of the Technical Society, as well as by many other representatives of the technical professions.

Mr. Percy was one of the foremost architects of California, having built some of the largest and finest buildings in San Francisco. The Journal contains several professional papers from his pen on architectural subjects.

His death is a great loss to the Society, whose staunch friend and supporter he had always been.

In proper time a suitable memorial to his name will be drawn and sent to the Journal for publication.

Mr. Percy was born in Bath, Me., and was fifty-three years old at the time of his death.

Engineers' Club of St. Louis.

514th Meeting, November 7.—The meeting was called to order at 8.30 p.m., at the Office Men's Club, with President W. S. Chaplin in the chair. Twenty-seven members and eighteen visitors were present. The minutes of the 513th meeting were read and approved. The names of Frederick P. Spaulding, Francis J. Llewellyn and Warren A. Tyrell were proposed for membership in the Club. A letter was received from Monsieur G. Eiffel, the distinguished French engineer, announcing the gift of two volumes on a scientific subject, of which he is the author. A communication was received from the Association of Engineering Societies, extending a general invitation to members of the Engineers' Club to discuss any of the papers appearing in the Journal, the discussion to be forwarded to the Secretary of the Association not later than three months from the date of publication of the paper.

The paper of the evening was on "The Steel Skeleton Construction of a High Office Building," by Mr. J. S. Branne.

Mr. Branne explained the origin and development of steel construction for high office buildings. He discussed the steel construction from the structural engineer's standpoint and exhibited various elevations, sections and floor plans. The paper treated of the foundations, floors, columns, wind bracing and typical details of a high office building.

The discussion was participated in by Messrs. Chaplin, Borden, Fay and Johnson.

Meeting adjourned. F. E. BAUSCH, *Secretary.*

515TH MEETING, NOVEMBER 21, 1900.—The meeting was called to order at 8.15 P.M., 1600 Lucas Place, with President W. S. Chaplin in the chair. Thirty-one members and nine visitors were present. The minutes of the 514th meeting were read and approved. The minutes of the 299th meeting of the Executive Committee were read. The names of Frederick P. Spaulding, Francis J. Llewellyn and Warren A. Tyrell were balloted for and unanimously elected.

A motion was made and carried to decline with thanks the proposal of the Office Men's Club to provide for Club quarters at a stipulated rental in its building, 3022 Olive street. It was moved and the motion unanimously carried that a committee of five be elected to form a committee on nominations for officers for the ensuing year. The five members so elected were Messrs. Ockerson, Hermann, Moore, Flad and Colby.

On motion of Mr. Pitzman, the motion being duly carried, the Chair appointed a committee of five—viz. Messrs. J. Pitzman, E. J. Spencer, William Bouton, H. H. Humphrey and A. H. Zeller—to solicit further subscriptions, increasing the Engineers' Club share of contribution to the World's Fair funds.

The Secretary was instructed to draft a letter to be mailed to members explaining the need of an increased subscription, inclosing also a blank form returnable to Mr. J. Pitzman.

The allotment to the Engineers' Club for World's Fair aid is $15,000. It is hoped that this sum will be promptly met and that the members will, individually, take an active interest.

The paper of the evening was on "Street Lighting of Cities," by Mr. H. H. Humphrey. The question of proper illumination of streets in a large city was thoroughly reviewed, the speaker referring to the recent developments in street illumination in St. Louis with a view to adopt a uniform and diffused light in preference to the one, as he expressed it, which gives brilliantly lighted crossings and Egyptian darkness in the middle of the blocks. The developments appear to be along the lines of the inclosed arc lamps and the improved mantle gas lamps quite familiar to St. Louisans. Comparisons were made between the direct-current series inclosed arc and the alternating series inclosed arc. The comparative difference in candle power of the two lamps with the same consumption of energy being unquestioned, the former lamp was adopted in connection with the new lighting contract. The city required 480 watts at the arc regardless of the candle power, but thanks to the engineers of the plant, at least in this instance, they give the public the benefit of the 10 per cent. increase in light

A general description of the new city lighting plant was given with a discussion of its principal engineering features, also a data sheet giving a test of one of the units and some data obtained from a test of another high-voltage plant.

A number of slides in connection with the city lighting plant were exhibited.

The discussion of the paper was participated in by Messrs. Humphrey, Flad, Kinealy, Bouton, Spencer, Roper, Reber and Hermann. The meeting adjourned to an adjoining room, where lunch was served.

F. E. BAUSCH, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., DECEMBER 19, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 P.M.; President Alexis H. French in the chair. Eighty-four members and visitors present.

The record of the last meeting was read and approved.

Messrs. William L. Blossom and Walter H. Sawyer were elected members of the Society.

The thanks of the Society were voted to Alexander Martin, agent of the Cunard Steamship Company, Limited, and to Captain Pritchard and Chief Engineer MacFarlane, of the "Saxonia," for courtesies extended on the occasion of our visit to the steamship "Saxonia" on Thursday, December 6; also to the New England Electric Vehicle Transportation Company for courtesies extended to us this afternoon on the occasion of our visit to its plant.

Mr. Albert S. Cheever read the first paper of the evening, entitled "Stone Arch Bridges Recently Constructed on the Fitchburg Railroad." Mr. James W. Rollins, Jr., followed with a paper on "Arch Centers." Both papers were profusely illustrated by lantern views.

Adjourned. S. E. TINKHAM, *Secretary.*

Montana Society of Engineers.

AT a special meeting of the Society held on November 24, Butte was selected as the place for holding the annual meeting, and the dates January 10, 11 and 12, 1901. President Blackford appointed the following committees:

On Transportation—H. W. Turner.

On Arrangements—R. A. McArthur, E. H. Wilson, G. W. Tower, Jr., C. H. Moore and Eugene Carroll.

THE regular meeting was held on December 8, 1900; President Blackford in the chair. Seven members present. Charles H. Bowman and George T. Ingersoll, both of Butte, were elected to membership.

The Committee on Transportation for the annual meeting reported that the Northern Pacific Railroad and the B. A. and P. Ry. Companies had replied to his request for a single fare for members and visitors to the annual meeting, and both had kindly granted the same. The Great Northern and the Oregon Short Line Companies had not yet replied owing to short time, but he had been assured that the answers would be satisfactory.

The Committee on Arrangements reported progress, and promised to issue a preliminary program of the meeting in a few days. There being no further business, the meeting adjourned.

ROBERT A. MCARTHUR, *Secretary.*

Engineers' Society of St. Paul.

St. Paul, Minn., December 3, 1900.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 p.m. Present, seven members and one visitor. President Powell in the chair. Minutes of previous meeting read and approved.

Mr. George S. Edmondstone and Mr. Noah Johnson were elected to membership.

No paper or discussion preceded adjournment.

C. L. Annan, *Secretary.*

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When reprints are wanted, notice of the fact, stating how many are desired and whether they are to be furnished with covers, should accompany the paper when it is sent to the Secretary of the Association.

If the paper has been discussed, please state whether it is desired that the reprint shall contain the discussion.

JOHN C. TRAUTWINE, Jr., Secretary,
257 SOUTH FOURTH STREET,
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